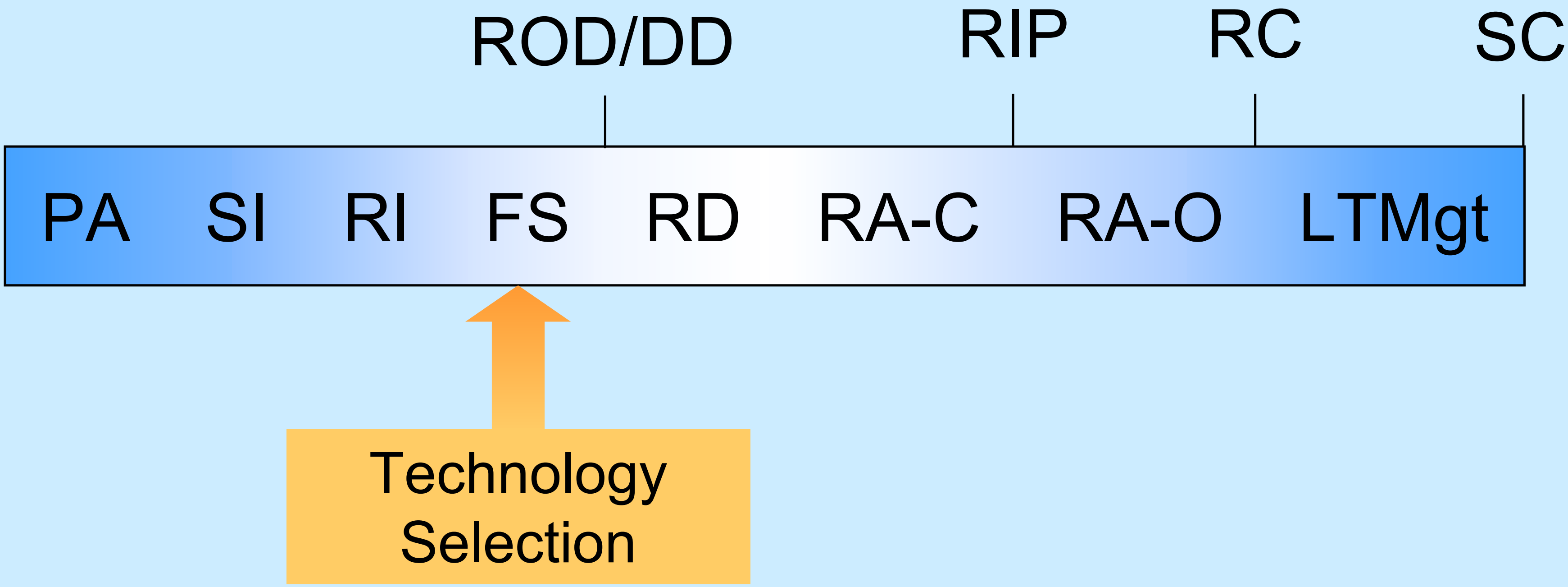
Sediments Part 2: Cleanup Alternatives

NAVFAC

Sediment Cleanup Alternatives
Overview

- Establishing Sediment Cleanup Criteria
  - Information Requirements
  - Regulations and ARARs Governing Sediment Remediation
  - Establishing Risk-Based Criteria
- Natural Recovery
- In Situ Capping
- Environmental Dredging
- In Situ Remediation (innovative treatment alternatives)
- Summary

IR Process


ROD/DD
RIP
RC
SC
PA
SI
RI
FS
RD
RA-C
RA-O
LTMgt
Technology
Selection

Information Requirements

- Planning considerations
  - FS-related data
  - Source identification and PRPs
  - Source control measures and efficacy
  - Anticipated future land use
  - Potential ARARs
- Determining remediation goals and cleanup levels
  - Contaminant-specific
  - Site-specific
  - Area and depth of contamination

Sedment Cleanup Alternatives

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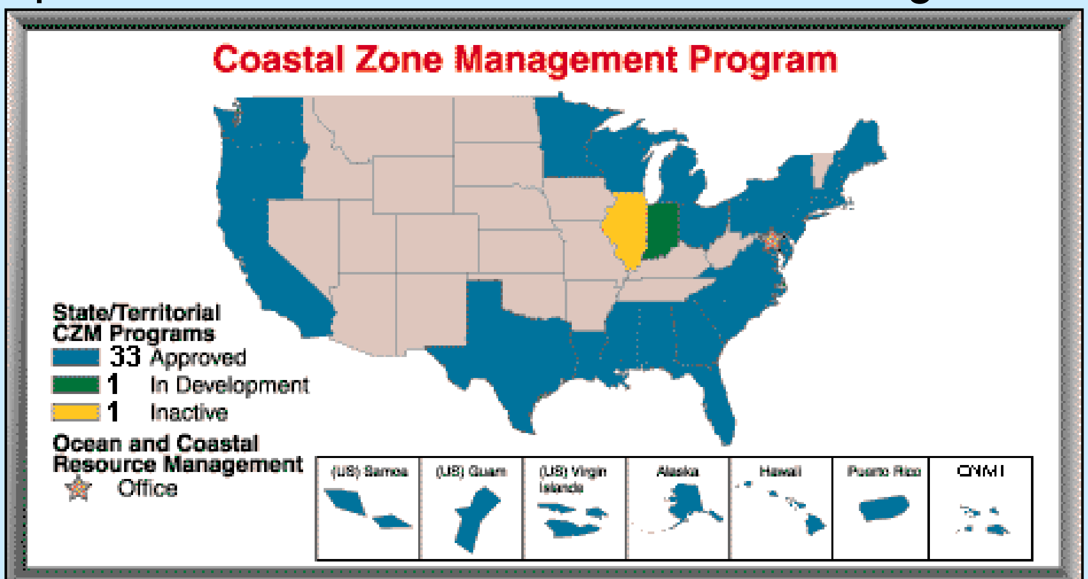
Regulations and ARARs

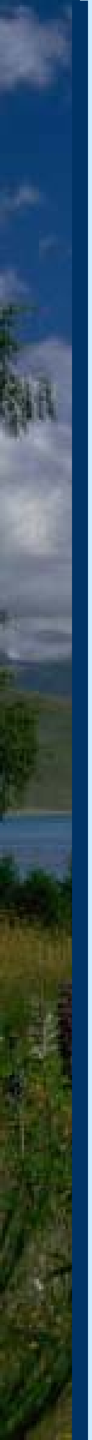
- **CERCLA, RCRA, and TSCA**
  - Regulates site cleanup, hazardous/toxic waste treatment, and land disposal Clean Water Act, Section 404 (CWA) – Prohibits discharge of dredged material into wetlands without a permit
- **Rivers and Harbors Act (RHA), Section 10**
  - Requires permits for aquatic structures, or work in or affecting navigable waters
- **Coastal Zone Management Act (CZMA)**
  - State programs promote economic growth compatible with natural resource protection



http://www.ocrm.nos.noaa.gov/czm/czmsitelist.html

Regulations and ARARs (cont.)

- **Marine Protection, Research, and Sanctuaries Act (MPRSA), Section 103 Ocean Dumping Act (ODA)**
  - Regulates ocean disposal of dredged material
- **Water Resources Development Act (WRDA)**
  - Public works legislation covering navigational and flood control projects; also addresses beneficial use and funding for major sediment projects
- **Others**
  - Fishery Conservation and Management Act
  - National Environmental Policy Act (NEPA)
  - Endangered Species Act



Sediment Cleanup Alternatives
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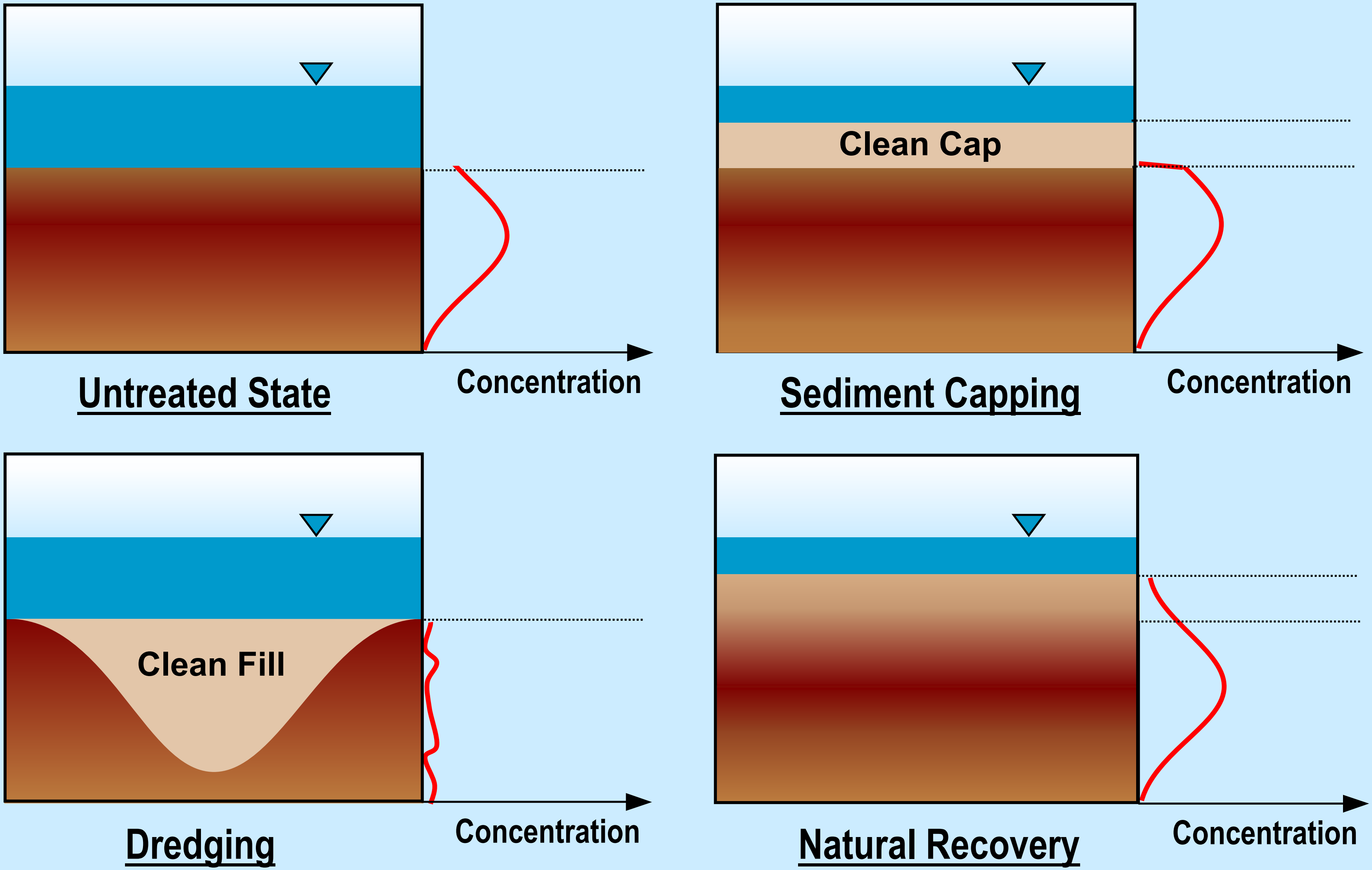
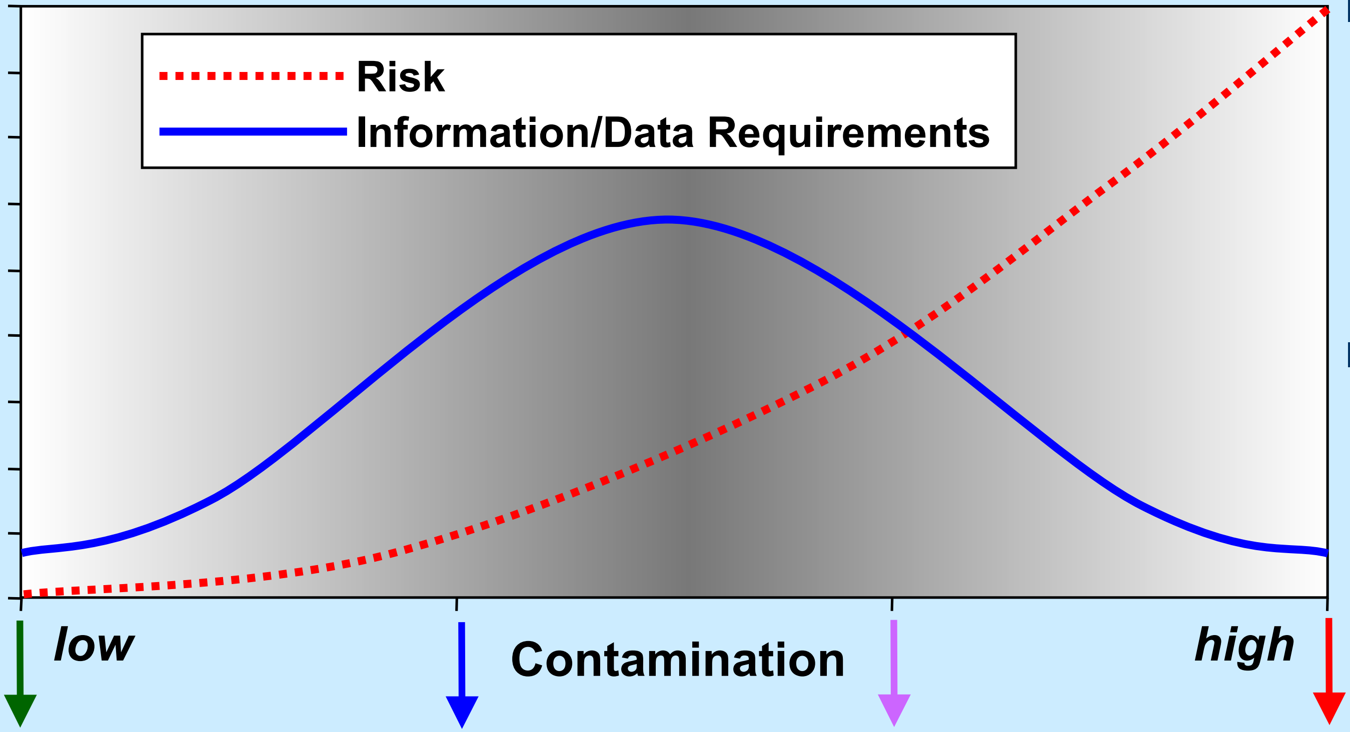
Common Goals of Sediment Cleanup

- Remove contaminated sediments from the environment
- Obstruct contaminant migration into the environment
- Limit or prevent environmental, ecological, and human exposure to sediment contaminants

Sediment Remedial Options, Overview



Sediment Cleanup Options Determined by Risk



- Uncontaminated or highly contaminated sediments require little data for management decisions
- Careful evaluation is required for “gray areas”

NFA

Contaminants present little or no significant risk

MNR

Contaminants present; relatively low risk; system will recover in a reasonable time

CAD/Cap

Contaminants present and impose significant risk; pathways can be controlled

Dredge

Contaminants present; high risk; removal is the best option

Chadwick and Apitz, 2001

Hunters Point
Weight of Evidence (WOE) Evaluation

Establishing the FS footprint

- Identify WOE parameters (e.g., concentration, toxicity)
- Score parameter weights for site parcel
- Integrate weights for all parameters
- Map WOE results
- Identify areas according to NFA, areas of potential concern, and high-risk areas

Hunters Point
Low-Volume Footprint

- Estimated footprint volume = 120,000 CY
- Footprint based on exceedences of ER-Ms and other benchmark values
- No site-specific risk basis for footprint

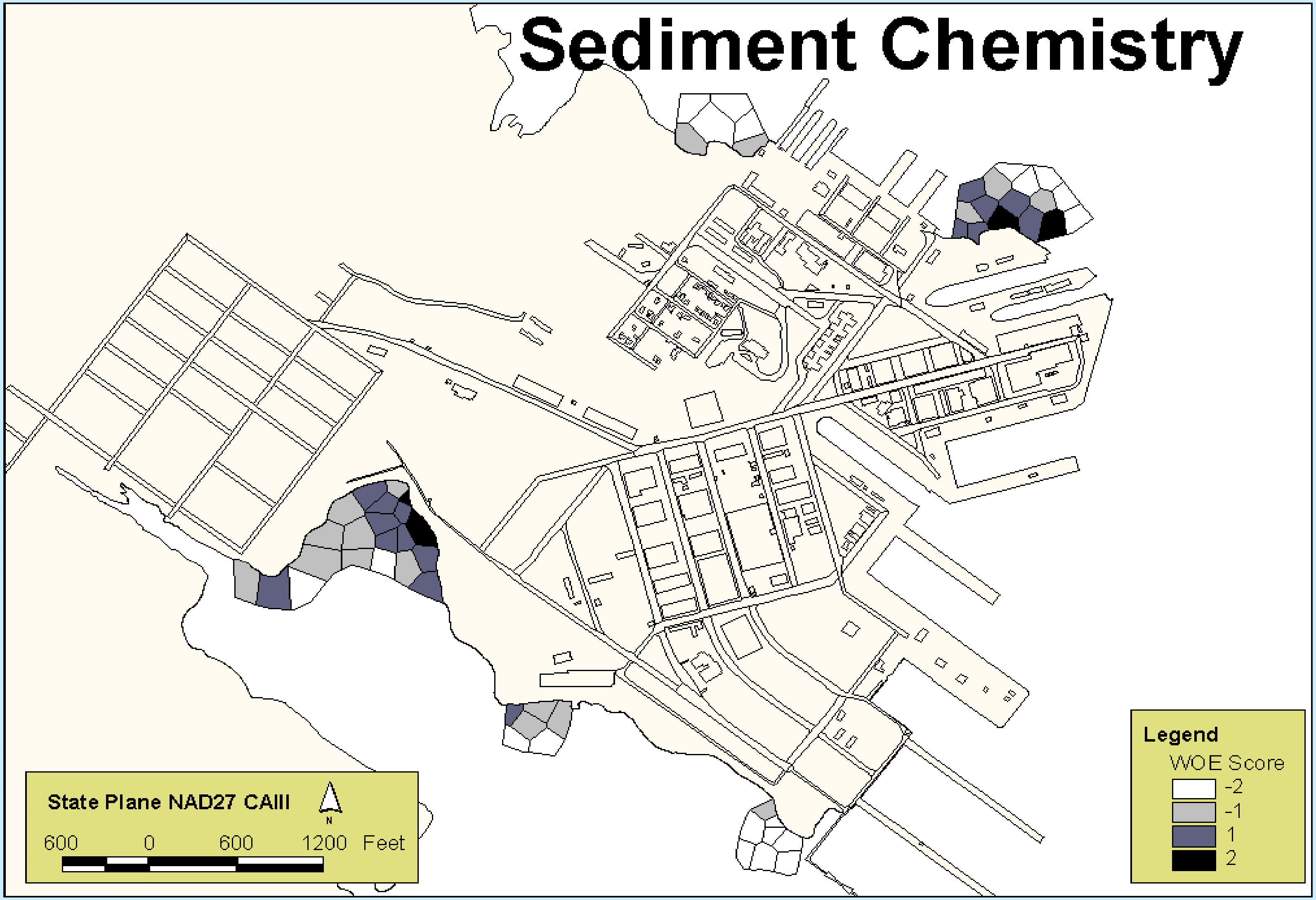
Hunters Point

Sediment Chemistry WOE Criteria

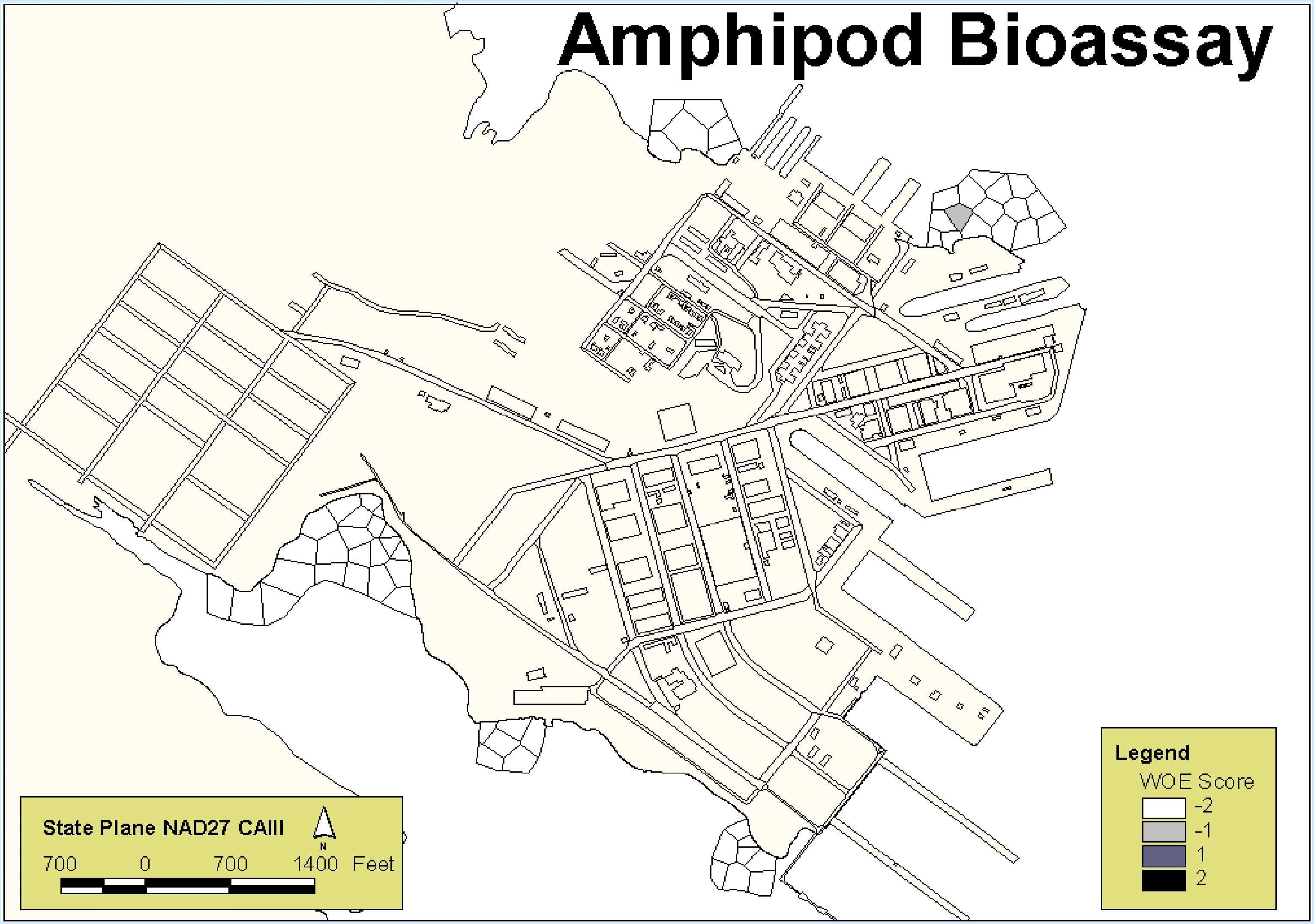
Score	Attribute	Sediment Chemistry	Amphipod Bioassay	Echinoderm Larvae SWI Bioassay	*Macoma* Bioaccumulation
+ 2	High Positive	• ERM-Q > 1.25 **or** • 7 or more COPECs > ER-Ms **or** • Any one COPEC > 10X its ER-M	≤ 50% survival relative to control response	≤ 50% normal development relative to control response	One or more priority COPECs or two or more non-priority COPECs exceed reference and • HQ_{low} > 10 **or** • HQ_{high} > 1
+ 1	Low Positive	• ERM-Q > 0.5 but ≤ 1.25 **or** • 4-6 COPECs > ER-Ms **or** • Any one COPEC > 5X its ER-M	> 50% but ≤ 69.5% survival relative to control response	> 50% but ≤ 60% normal development relative to control response	One or more priority COPECs or two or more non-priority COPECs exceed reference and • HQ_{low} ≤ 10 • HQ_{high} ≤ 1
– 1	Low Negative	• ERM-Q ≤ 0.5 but > UTL of ambient ERM-Q (0.3) **or** • 1-3 COPECs > ER-Ms	> 69.5% but ≤ 80% survival relative to control response	> 60% but ≤ 80% normal development relative to control response	No priority COPECs or no more than one non-priority COPEC exceeds reference and HQ_{low} ≤ 1
– 2	High Negative	• ERM-Q ≤ TL of ambient ERM-Q (0.3) **or** • All individual COPECs < ER-Ms	> 80% survival relative to control response	> 80% normal development relative to control response	No COPEC concentrations in HPS tissues exceed reference

Hunters Point

Sediment Chemistry WOE Map

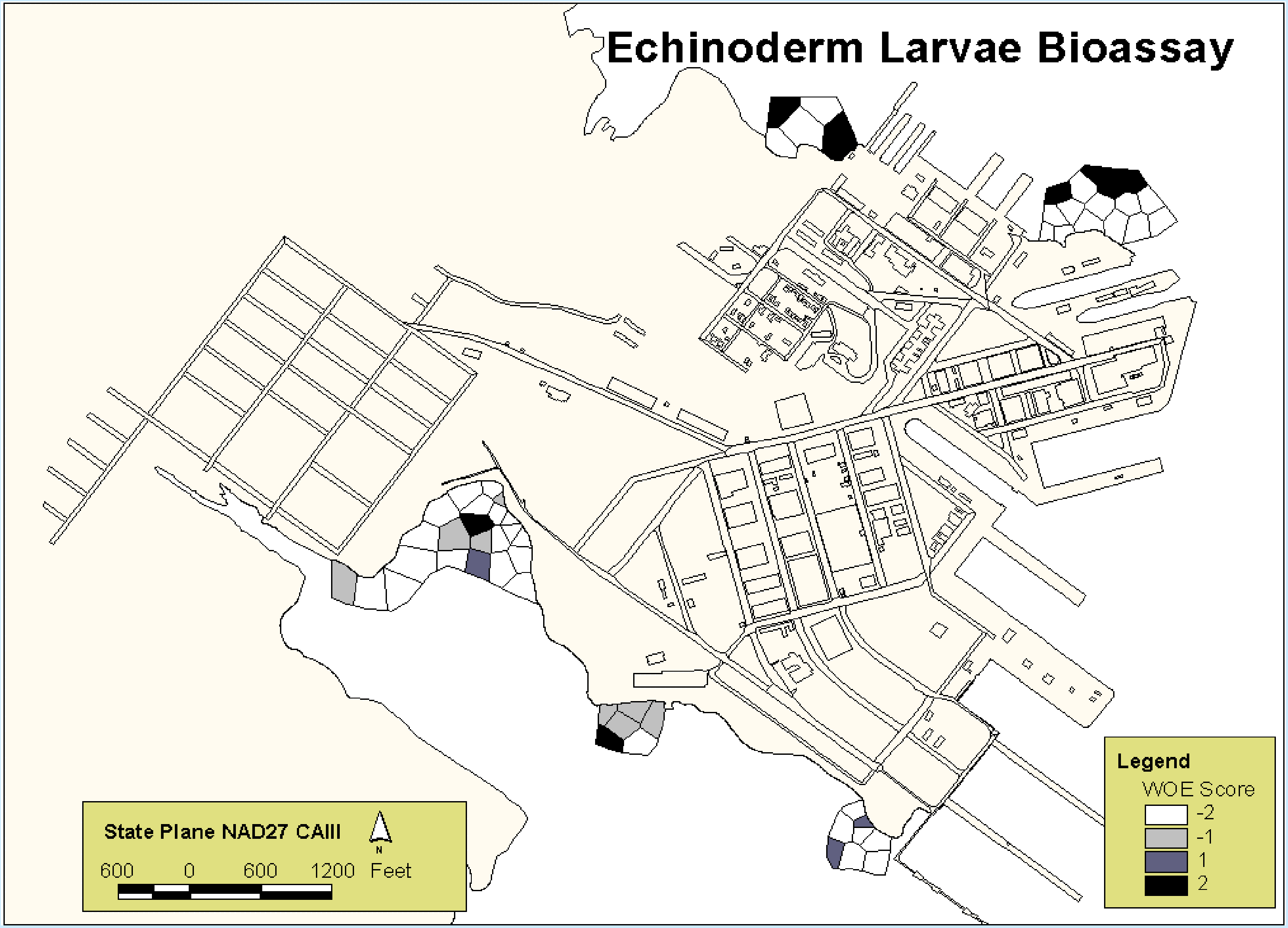


Hunters Point
Amphipod Bioassay WOE Map



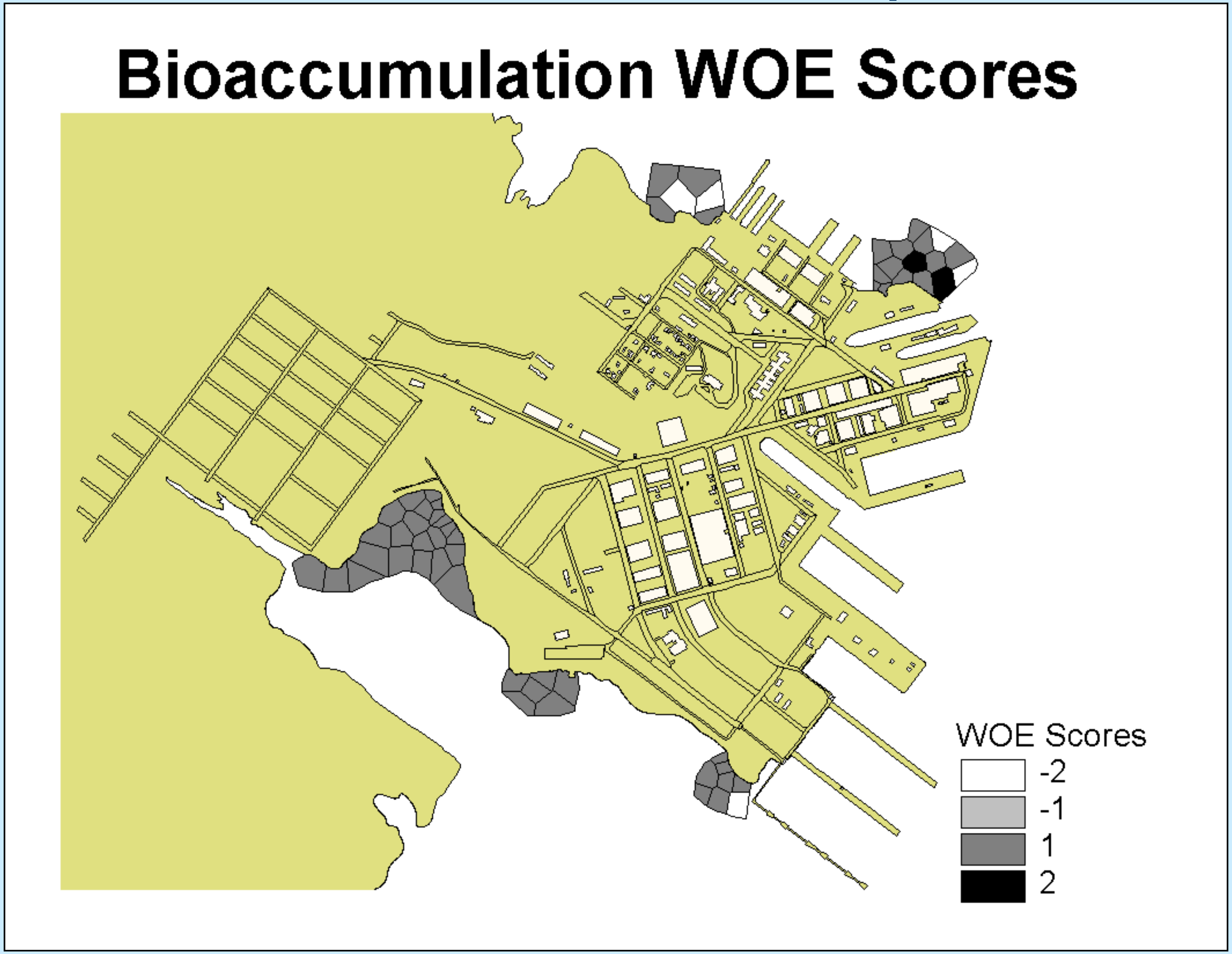
Hunters Point

SWI Larval Bioassay WOE Map



Hunters Point

Bioaccumulation WOE Map



Hunters Point

Integrated WOE Criteria

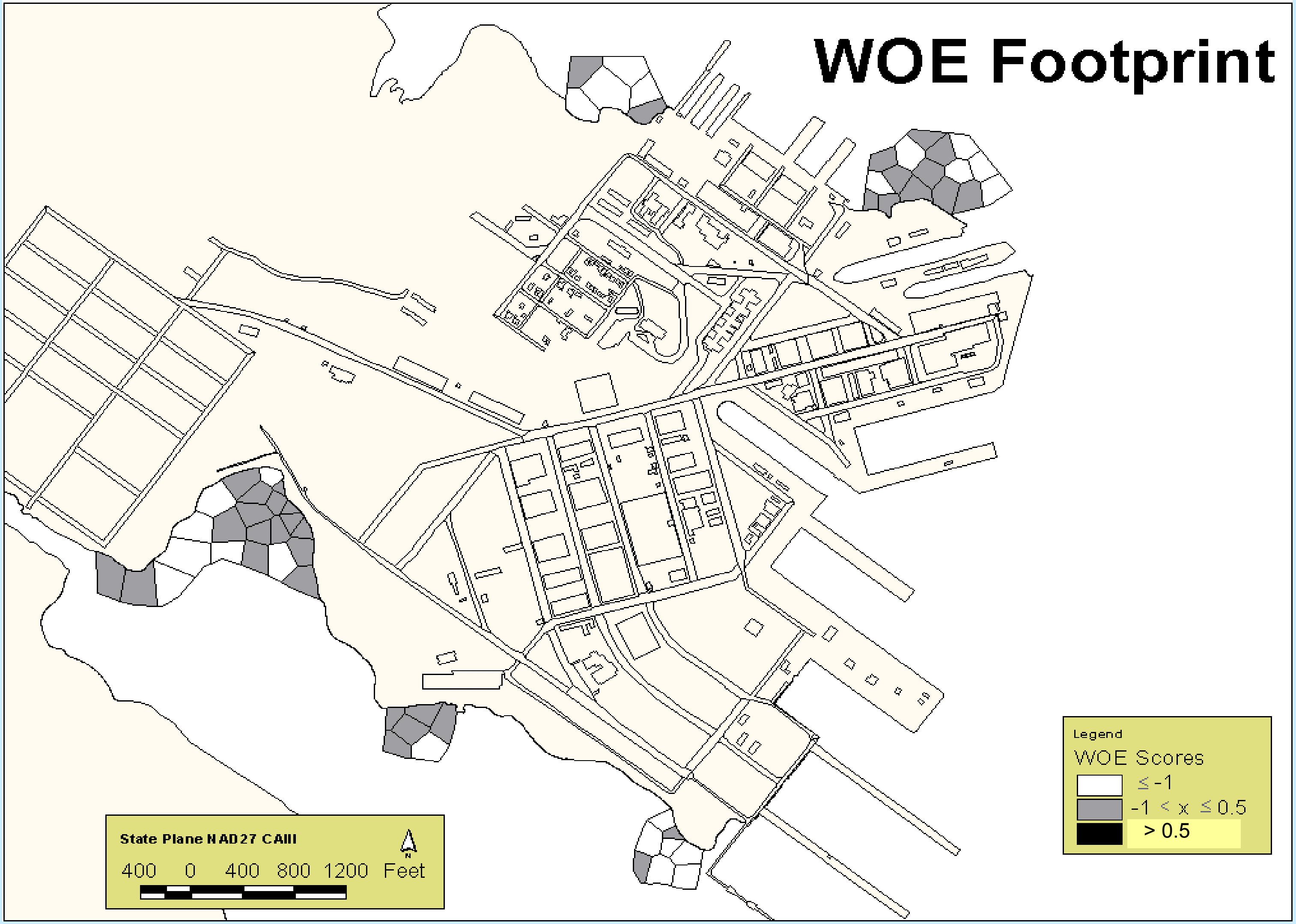
- WOE score > 0.5
  validates inclusion in FS footprint

- WOE score $\leq$ 0.5 to > -1
  gray area, requires further evaluation

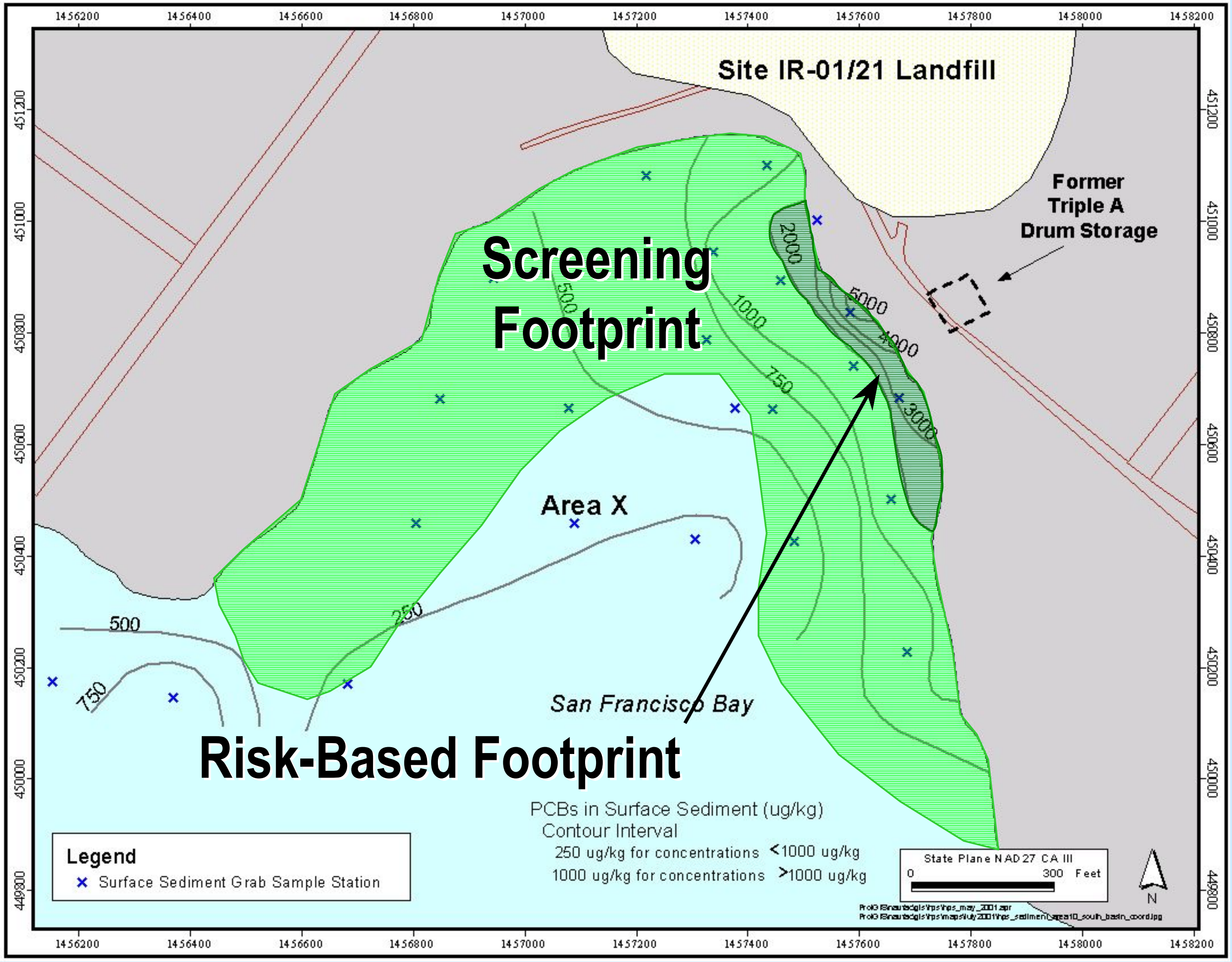
- WOE score $\leq$ -1
  validates exclusion from FS footprint

Hunters Point

Integrated WOE Results Map

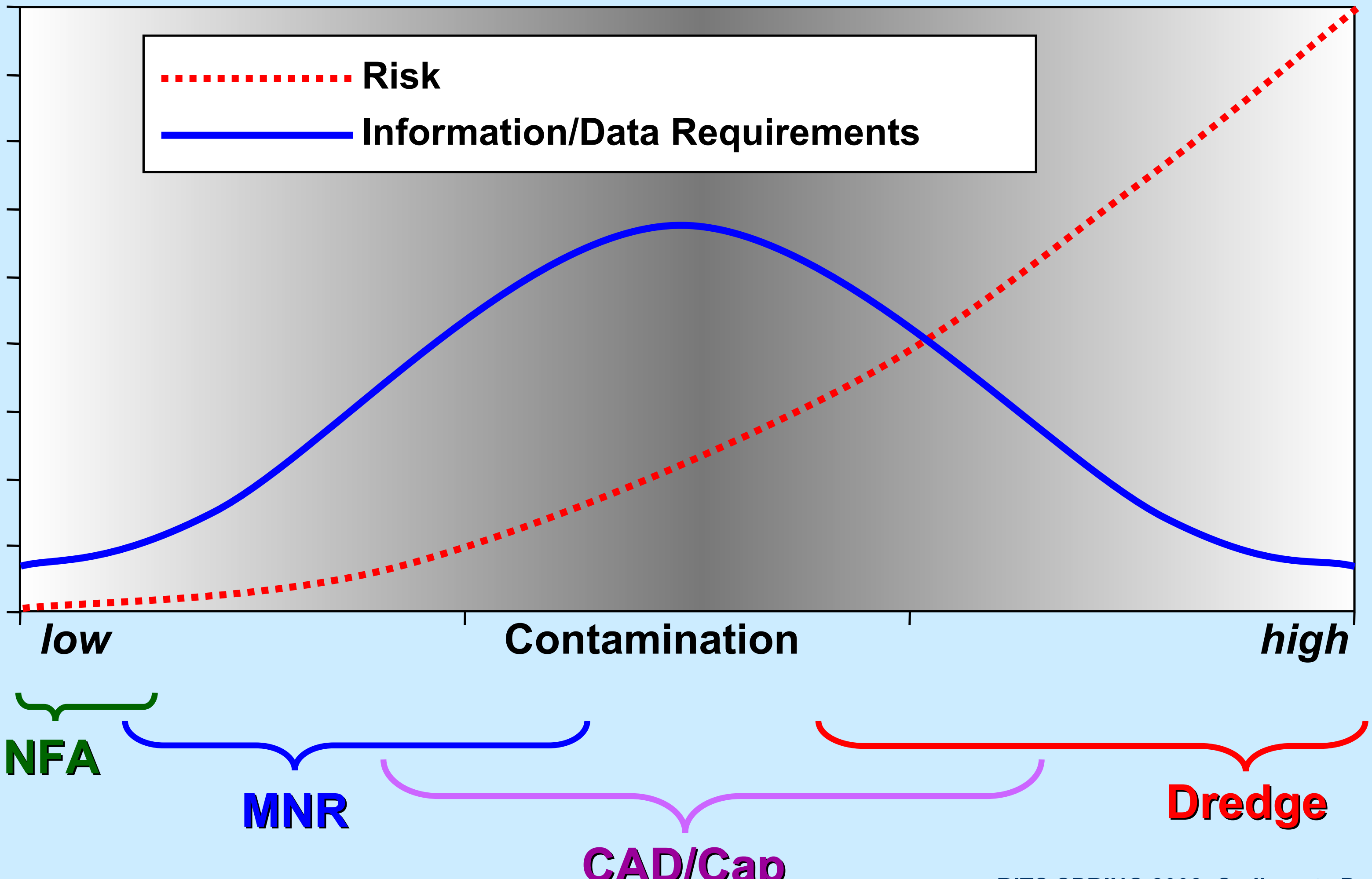


CNO Sediment Policy Statement #4
Risk-Based Cleanup



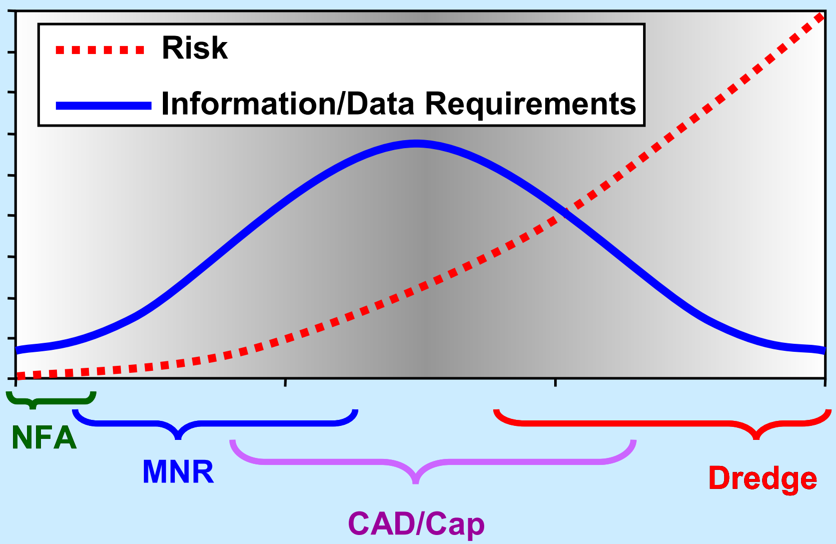
Sediment Cleanup Options Determined by Risk

Using an INTEGRATED approach



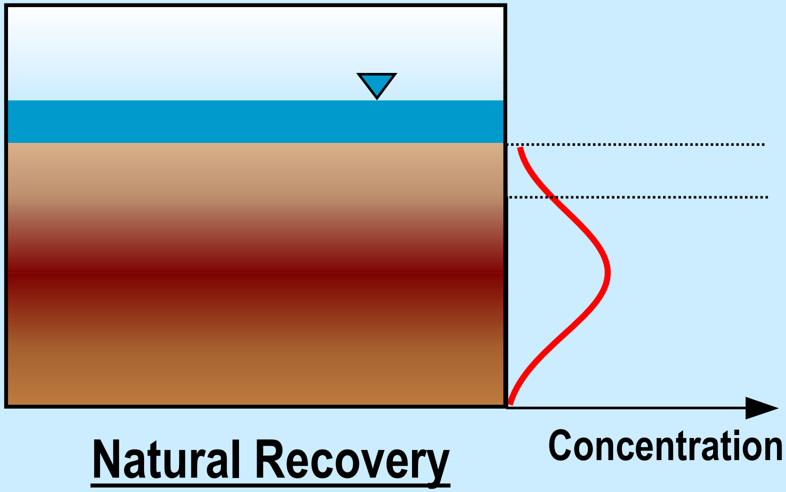
Sediment Cleanup Alternatives
Overview

- Establishing Cleanup Criteria
- Natural Recovery
  - Leave sediments in place at low-risk sites
  - Monitored Natural Recovery (MNR)
- In Situ Capping
- Environmental Dredging
- In Situ Remediation (innovative alternatives)
- Summary

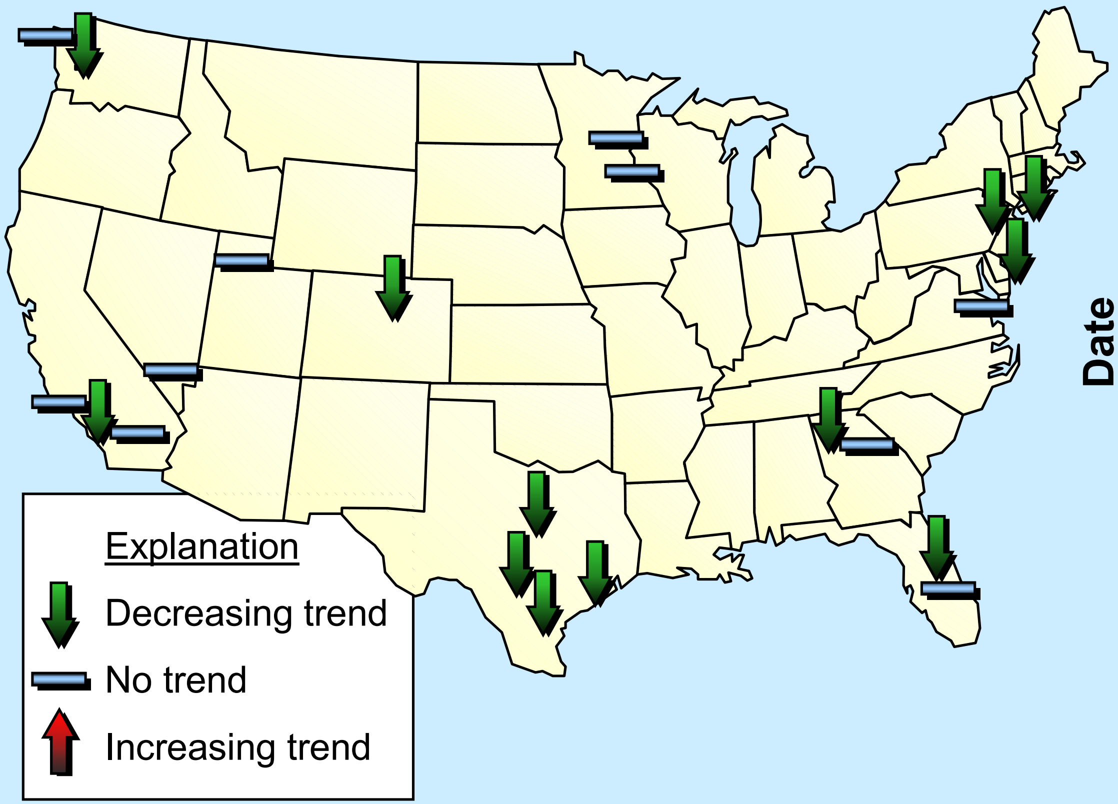


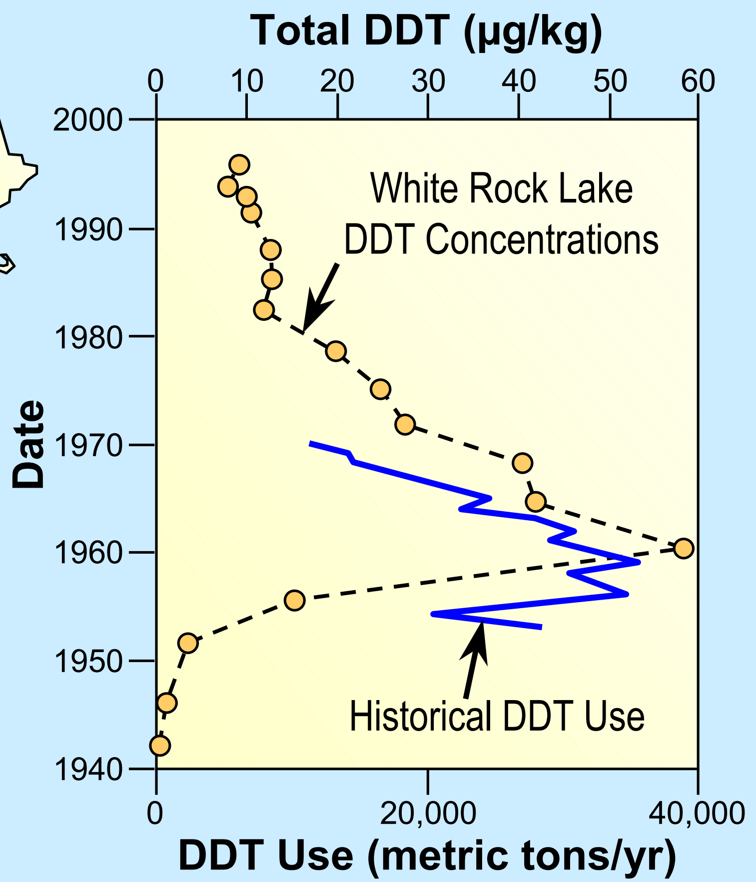
Principal Recovery Mechanisms

- Remedial option that relies on **natural environmental processes** to **permanently reduce risk**, and which includes **careful assessment** and **monitoring** to ensure success
- Natural capping (containment)
  - Requires net depositional areas
  - **Requires source removal**
- Contaminant weathering
  - Biological transformation
  - Chemical transformation
  - Physical dissolution, volatilization, sorption/sequestration



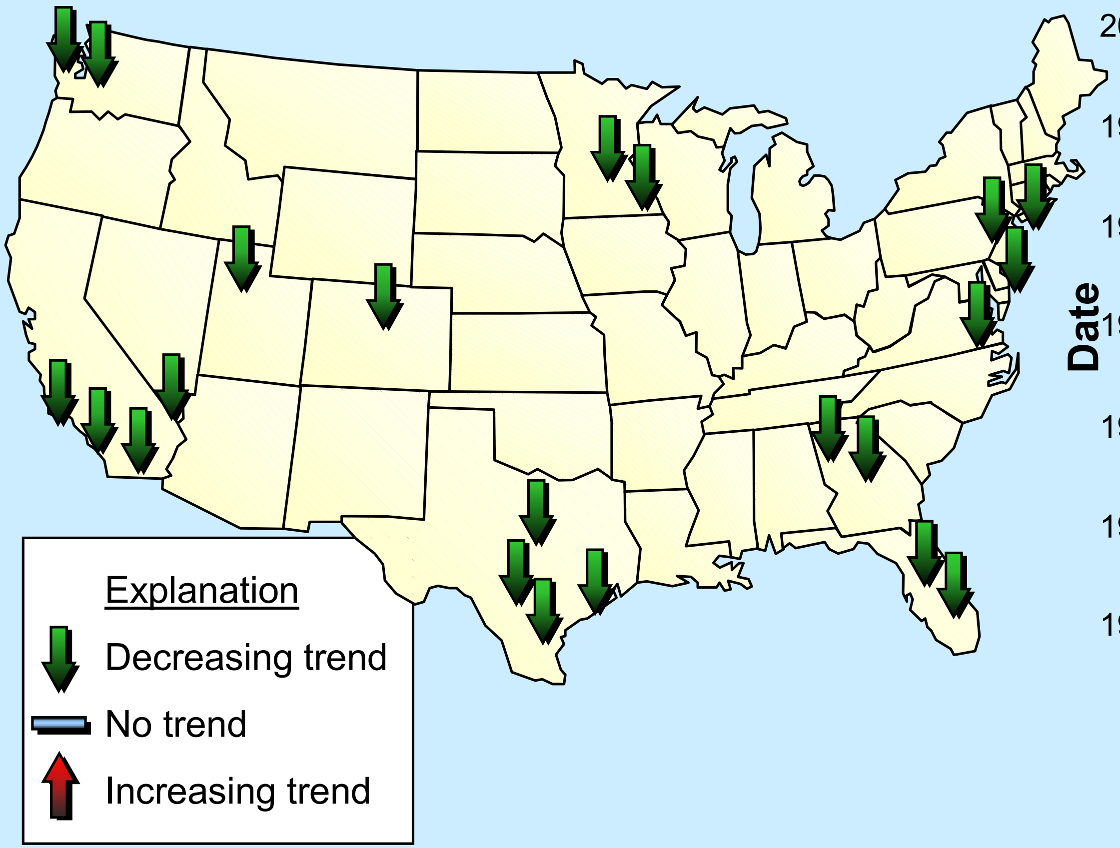
DDT Trends Throughout the United States

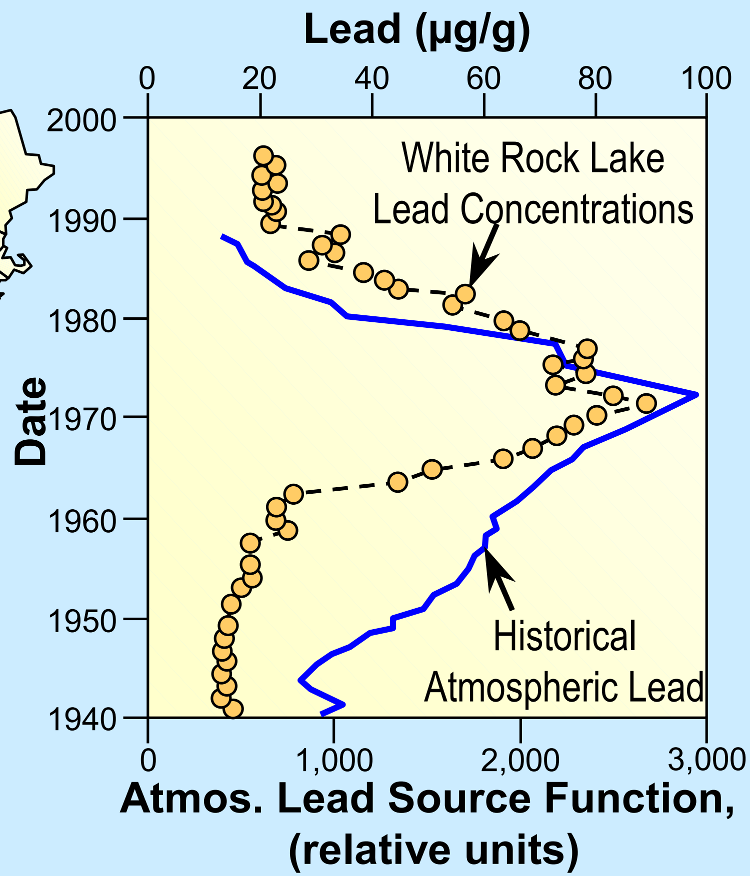




EPA-823-R-01-01
The Incidence and Severity of Sediment Contamination in Surface Waters of the United States (draft, 2001)

Lead Trends Throughout the United States





EPA-823-R-01-01
The Incidence and Severity of Sediment Contamination in Surface Waters of the United States (draft, 2001)

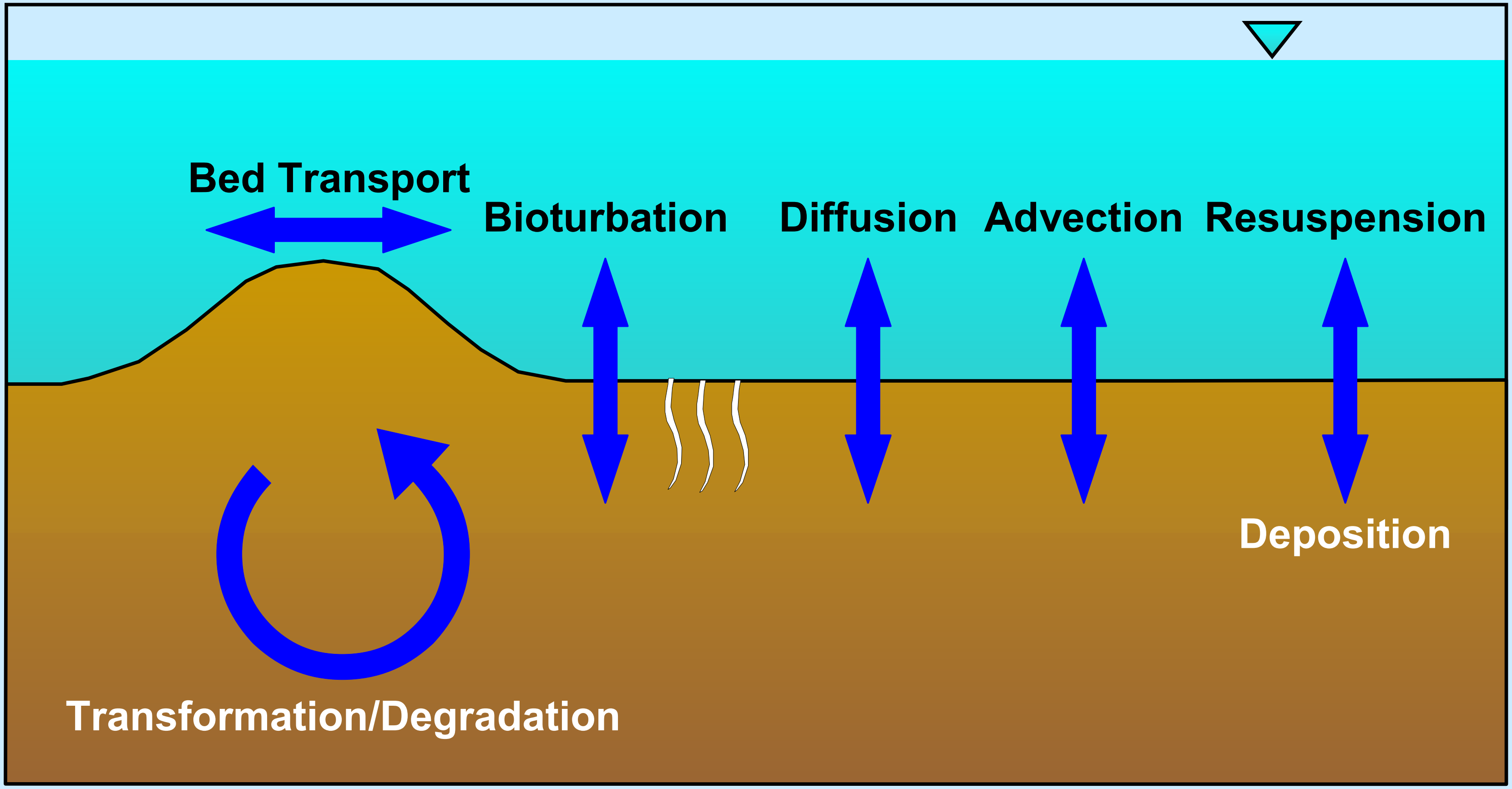
Advantages and Limitations

- Advantages
  - Takes advantage of natural processes to reduce risks
  - Relatively low-cost alternative
  - Minimizes short-term disturbance
  - Treatment/disposal not required
- Limitations
  - Contaminants remain in place
  - Process is very slow
  - May require long-term monitoring
  - Long-term site ownership
  - No formal guidance available

Applicability and Data Requirements

- Applicability
  - Net depositional areas
  - Relatively low-risk sites
  - Source must be removed or contained
  - Alternatives are impracticable
  - Public acceptance
- Information/Data Requirements
  - Horizontal and vertical contaminant distributions
  - Human health and ecological risks
  - Contaminant biodegradability and fate
  - Natural sedimentation rates
  - Benthic community uptake and exposure
  - Potential for sediments resuspension
  - Rate of contaminant transport (e.g., diffusion) to surface water

Pathway Ranking for In-Place Sediment Management (PRISM)



From Reible, D and Thibideaux, L (1999) "Using Natural Processes to Define Exposure From Sediments" Contaminated Sediment Management Technical Papers, http://www.smwg.org/index.htm.

POC: Dr. D. Bart Chadwick

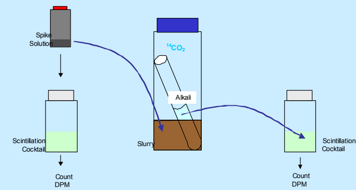
SPAWAR Systems Center, San Diego, D36

Prism Methods Development

BFSD

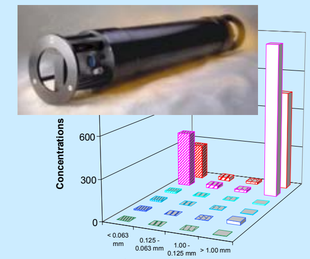
Microprofiler

Degradation assays



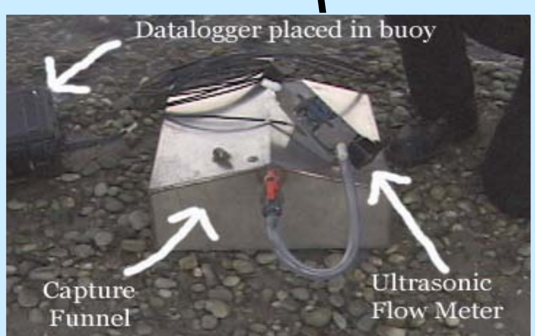
In situ flume

LISST/chemistry



flux = diffusion ± advection ± erosion
± bioirrigation ± degradation ± sedimentation

SPI



Seep meter

ADCP

Cores and chemistry

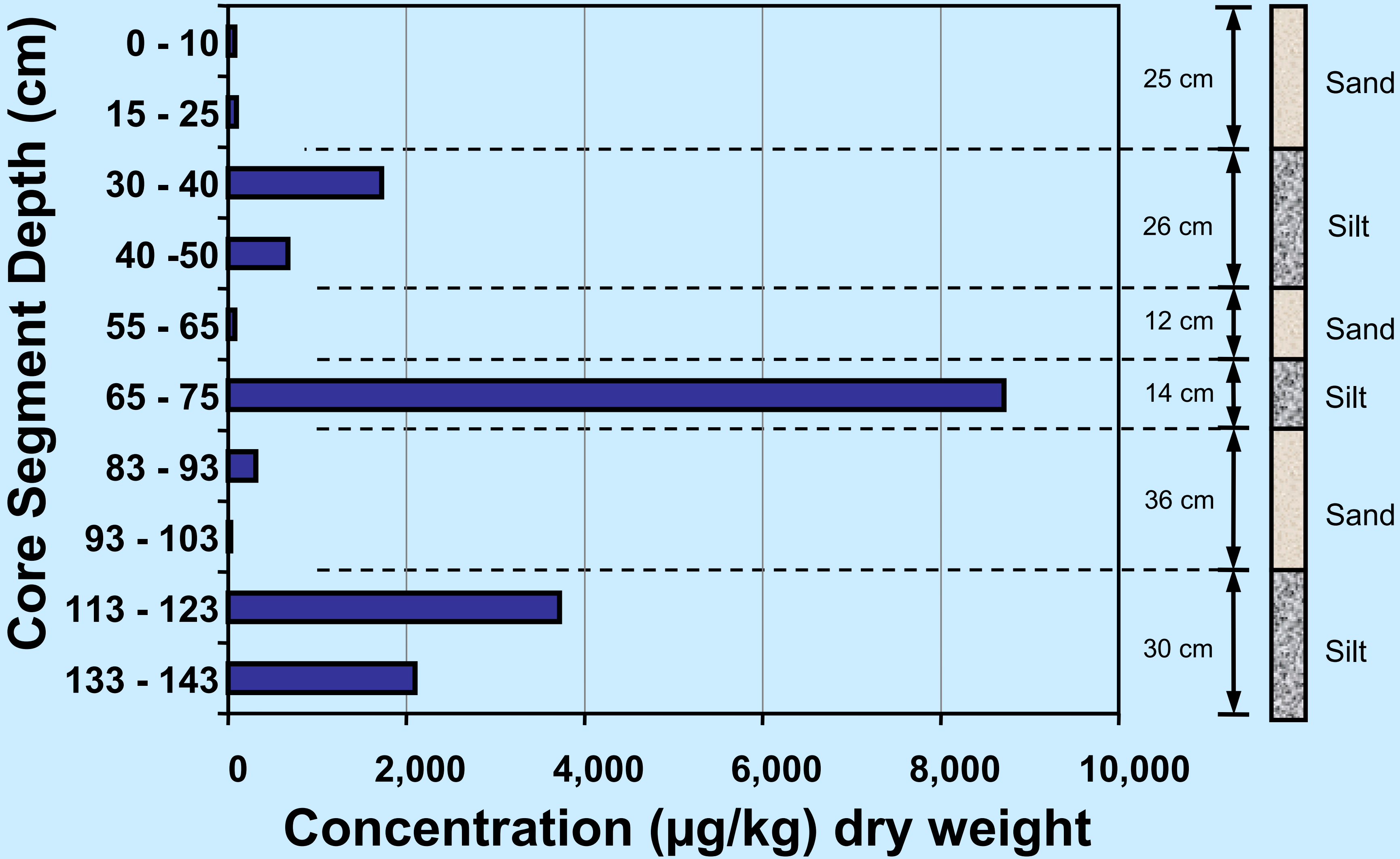
Chadwick and Apitz, 2001

Case Study
Lake Hartwell Superfund Site

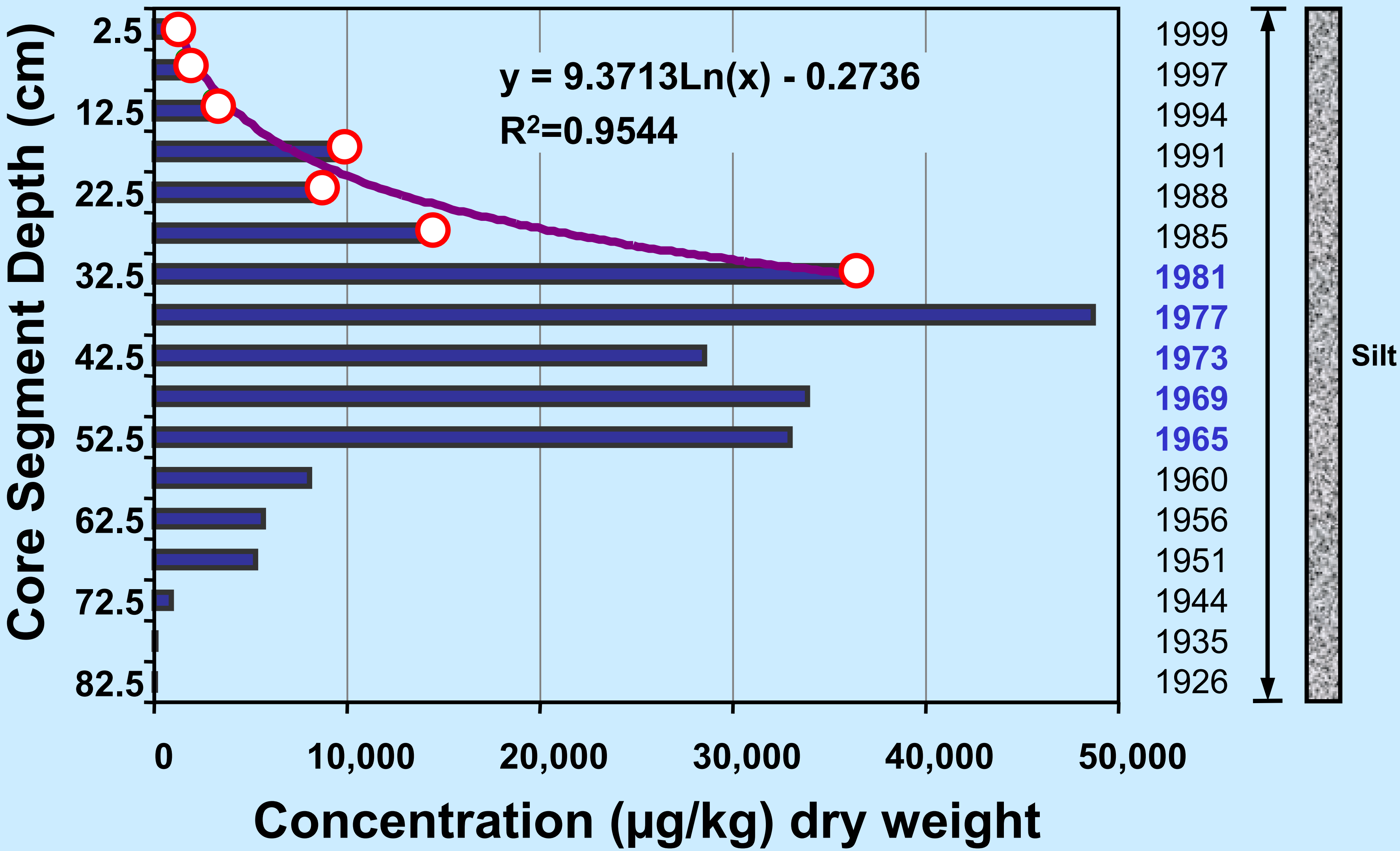
- Developed field evaluation techniques with the U.S. EPA
- Implemented techniques at the Lake Hartwell Superfund site
- Study objectives:
  - Surface recovery through sedimentation
  - Contaminant weathering (reductive dechlorination)

Lake Hartwell Sediment Core & Sample Collection

Lake Hartwell Upgradient Vertical PCB Profile (Silt/Sand Layering)



Lake Hartwell Downgradient Vertical PCB Profile (Silt Deposition)

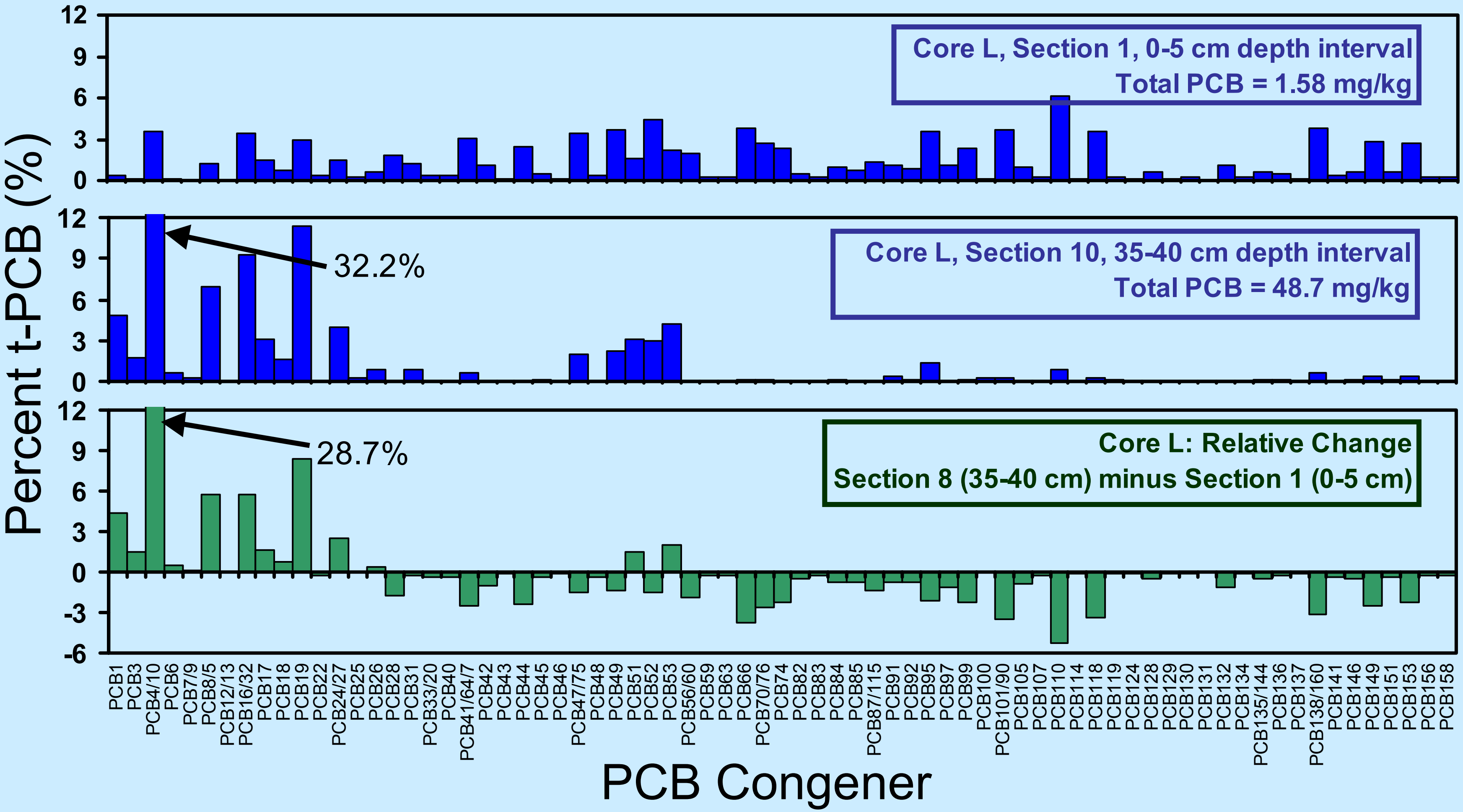


Lake Hartwell
Time (yrs) to Achieve Cleanup Goals

- U.S. EPA ROD Cleanup Goals
  - ROD surface sediment cleanup goal (U.S. EPA, 1994)
  - Mean site-specific sediment quality criteria (U.S. EPA, 1994)
  - NOAA effects range-low (U.S. EPA, 1994)

Time to Achieve Cleanup Goals		
1 mg/kg t-PCB	0.4 mg/kg t-PCB	0.05 mg/kg t-PCB
1 – 5 yrs	2 – 10 yrs	10 – 30 yrs

Lake Hartwell PCB Dechlorination



Less Cl^- — **More Cl^-**

Lower dioxin equivalents — **Higher dioxin equivalents**

Lake Hartwell Natural Recovery Program: Summary and Conclusions

- Highest t-PCB associated with silt/clay layers
- Decreasing surface t-PCB
  - Similar to nation-wide DDT and lead reductions
  - Approached 1.0 mg/kg
- Estimated time required to achieve target cleanup goals
  - 1 – 5 yrs for 1 mg/kg
  - 2 – 10 yrs for 0.4 mg/kg
  - 10 – 30 yrs for 0.05 mg/kg
- Demonstrated in situ reductive dechlorination
- Long-term risks: 100/500-yr storm events; LH dam stability?
- Ecological recovery not yet assessed

Salmon.asf

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- In Situ Capping
  - Engineering Sediment Caps
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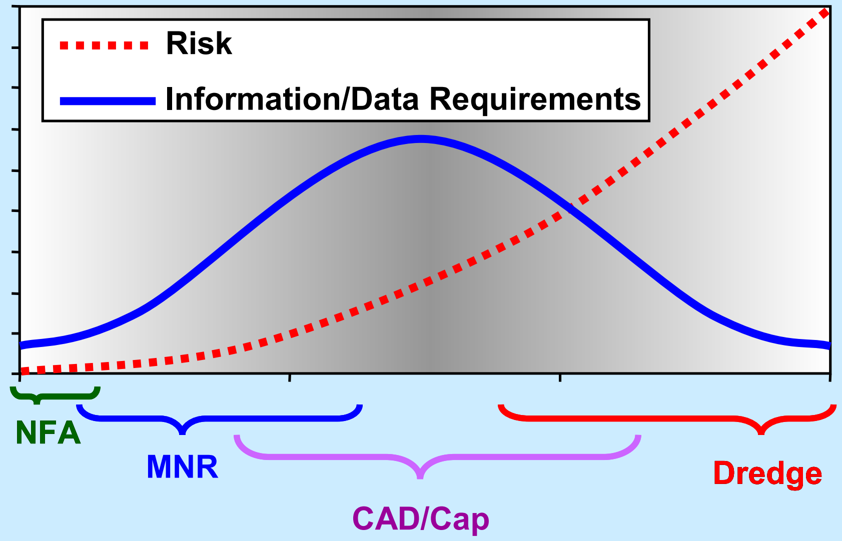
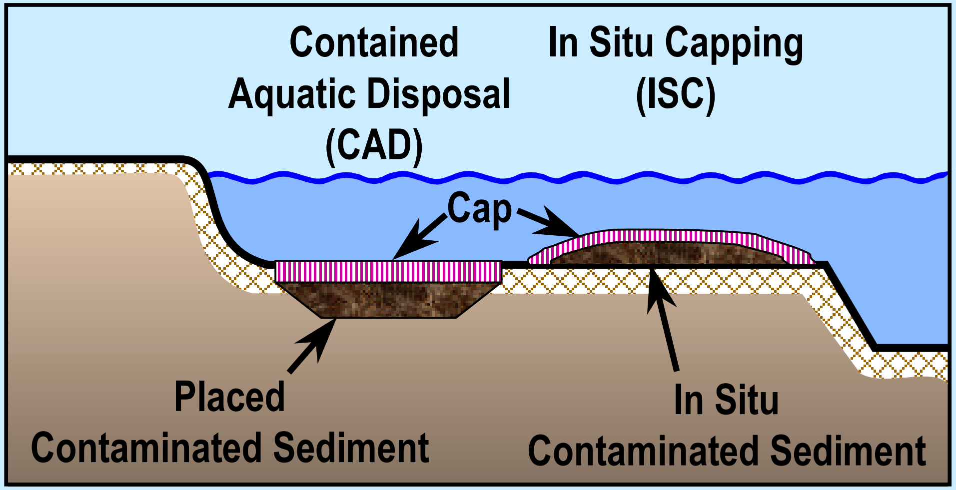


Principles and Application

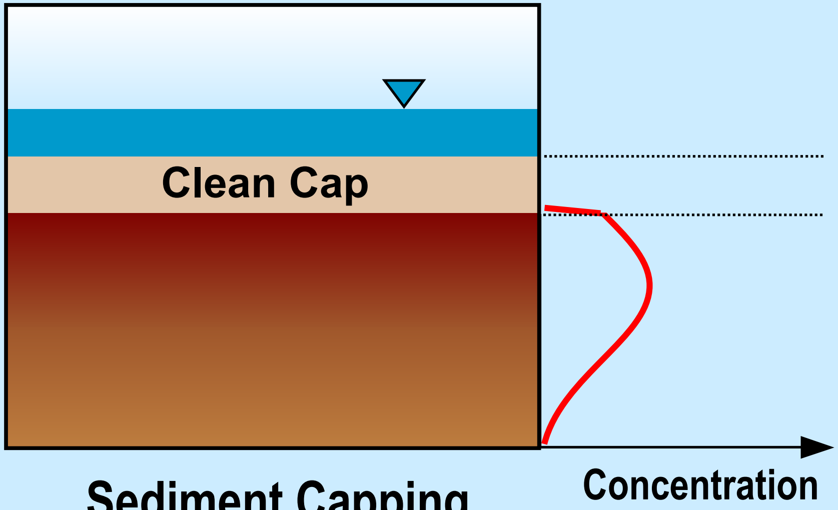
- Cover (cap) contaminated sediment in situ with clean material
  - Contaminated sediment is left in place or consolidated in a confined aquatic disposal (CAD) facility
  - Design options offer different types of caps
- Primary cap functions
  - Physically isolate contaminated sediment
  - Protect water column from contaminated sediment
  - Protect benthic environment from contaminated sediment
  - Create a clean sediment layer for a healthier benthic environment
- Application
  - Moderate to low-risk sites
  - Net depositional environments where cap remains stable
  - Non-navigational environments



Adapted from Palermo, 1991

Data Requirements

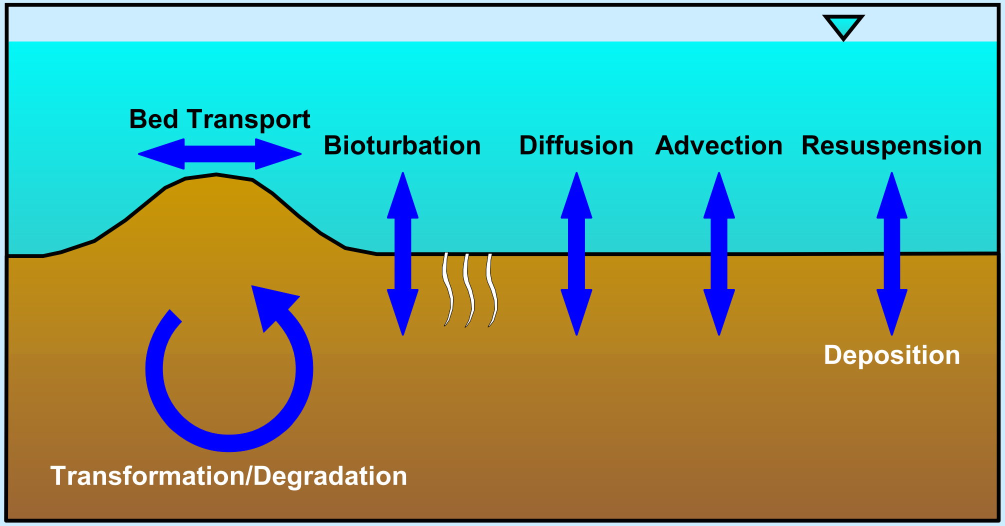
- Geotechnical
  - Sediment-bearing capacity
  - Cap-bearing capacity
  - Slope stability
  - Proposed cap geometry
- Hydraulic
  - Upward hydraulic gradients
  - Water column impacts during construction
  - Potential cap erosion (natural or ship-induced currents)
- Chemical
  - Contaminant characteristics and migration potential
  - Interaction between contaminants and sediment
  - Long-term fate of contaminants



Sediment Capping

Data Requirements (cont.)

- Benthic biota
  - Bioturbation from burrowing animals
  - Cap construction impact on local ecology
- Present and future site use
  - Minimum depth required for intended use (e.g., navigation)
  - Boat impacts (wake erosion, anchors)
  - Human health protection
  - Potential future disturbances (e.g., land-use changes)

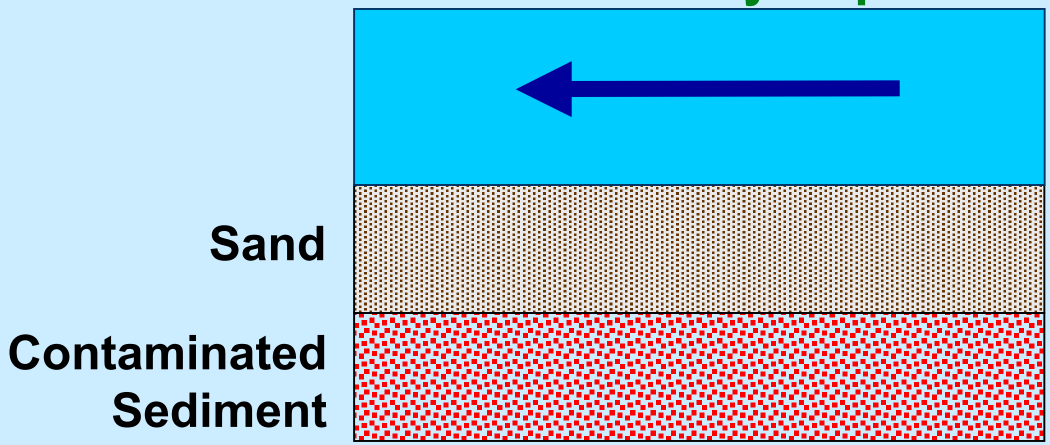


Cap Materials

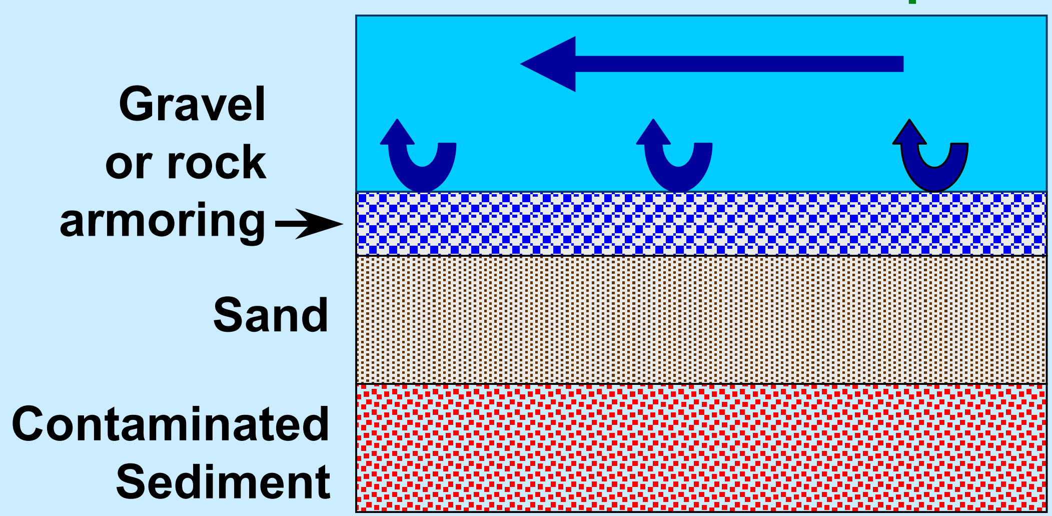
- Fine-grained materials
  - Reduced advection/diffusion
- Sand
  - Armoring, bulk depth, reduced suspension
- Gravel and cobbles
  - Armoring
- Geosynthetics
  - Reduce diffusion, advection, suspension; hot-spot cover

Cap Materials

Sand-Only Cap



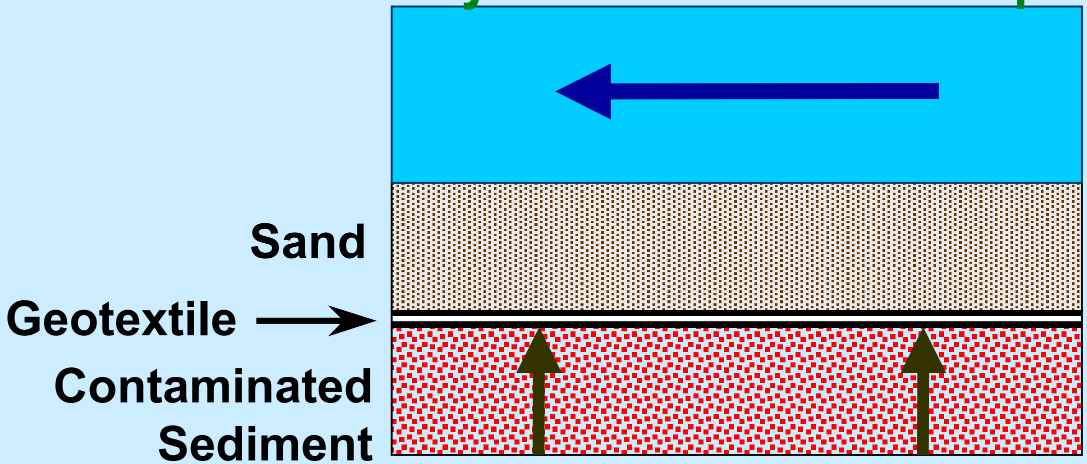
Armored Sand Cap



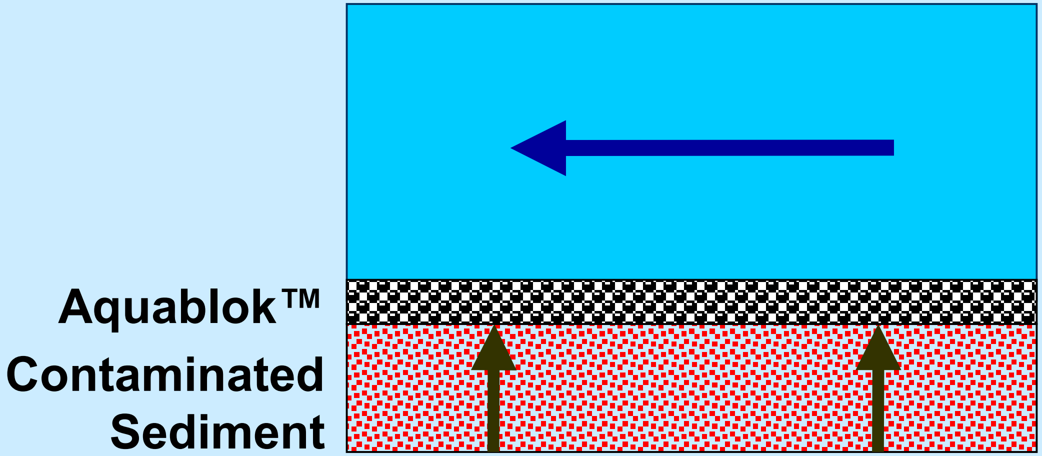
- **Create healthy surface-sediment environment**
- **Reduce sediment and surface water contact**
- Reduce sediment suspension
- Hinder contaminant transport
- Armoring prevents sediment suspension
- Moderate cost

Cap Materials

Synthetic/Geotextile Cap



Aquablok™

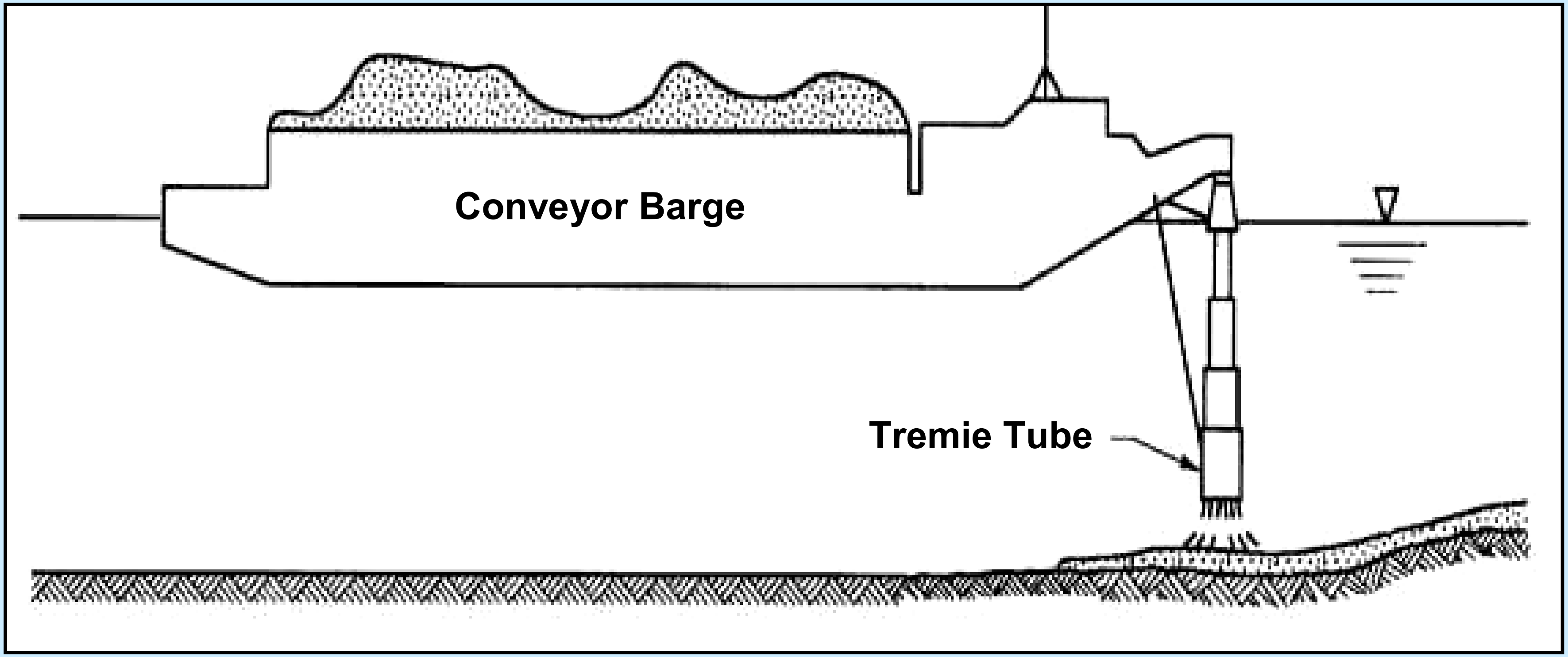


- Cover hot-spots
- Reduce sediment and surface water contact
- Hinder diffusion
- Prevent sediment suspension
- High-tech and relatively expensive

Cost Factors

- In situ capping is much less expensive than dredging and treating contaminated sediments
  - Manistique River capping cost was less than 1/6 the cost of dredging plus incineration
- Major cost factors
  - Whether contaminated sediment is consolidated
  - Measures required to protect local environment during capping
  - Source and quantity of capping materials
  - Size of area to be capped
  - Type of materials used in cap
  - Monitoring and cap maintenance

Cap Placement: Tremie Tube or Diffuser



Source: U.S. EPA, Assessment and Remediation of Contaminated Sediment (ARCS) Program: Guidance for In Situ Subaqueous Capping of Contaminated Sediments.

Cap Placement: Barge Dumping

Source: http://www.nws.usace.army.mil/geotech/ehcap/splithull.htm

Cap Placement: Washing Sediment from a Barge

Turbidity and Resuspension During Cap Placement

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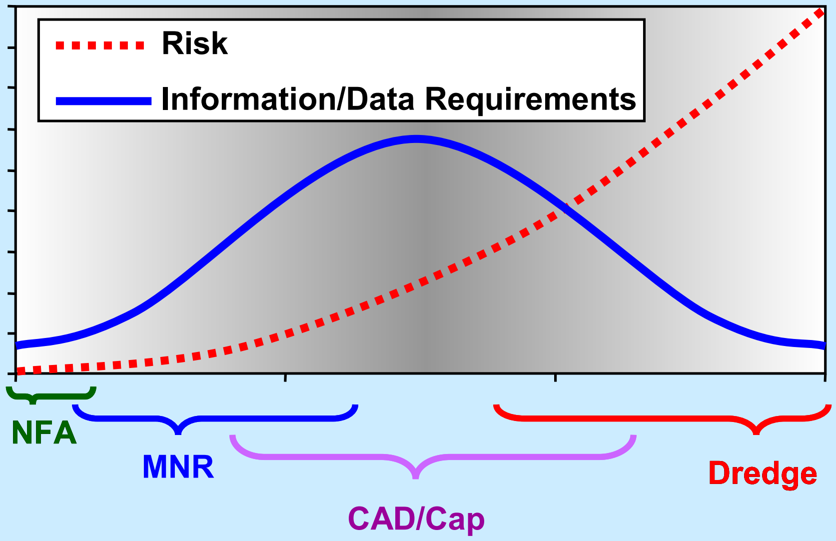


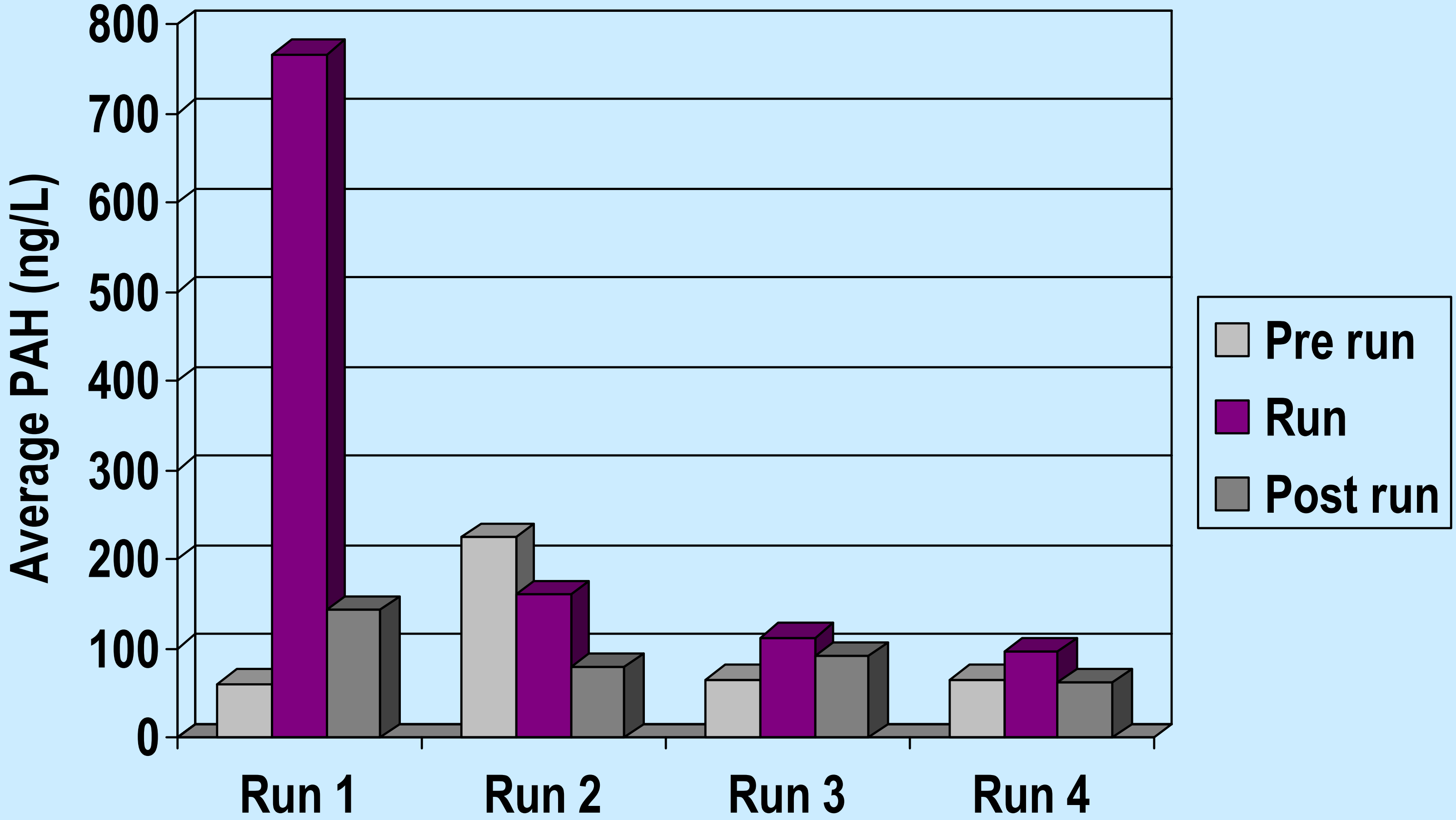
Turbidity and Resuspension
Case Study

Water-column monitoring during cap placement

Eagle Harbor, WA
Boston Harbor, MA

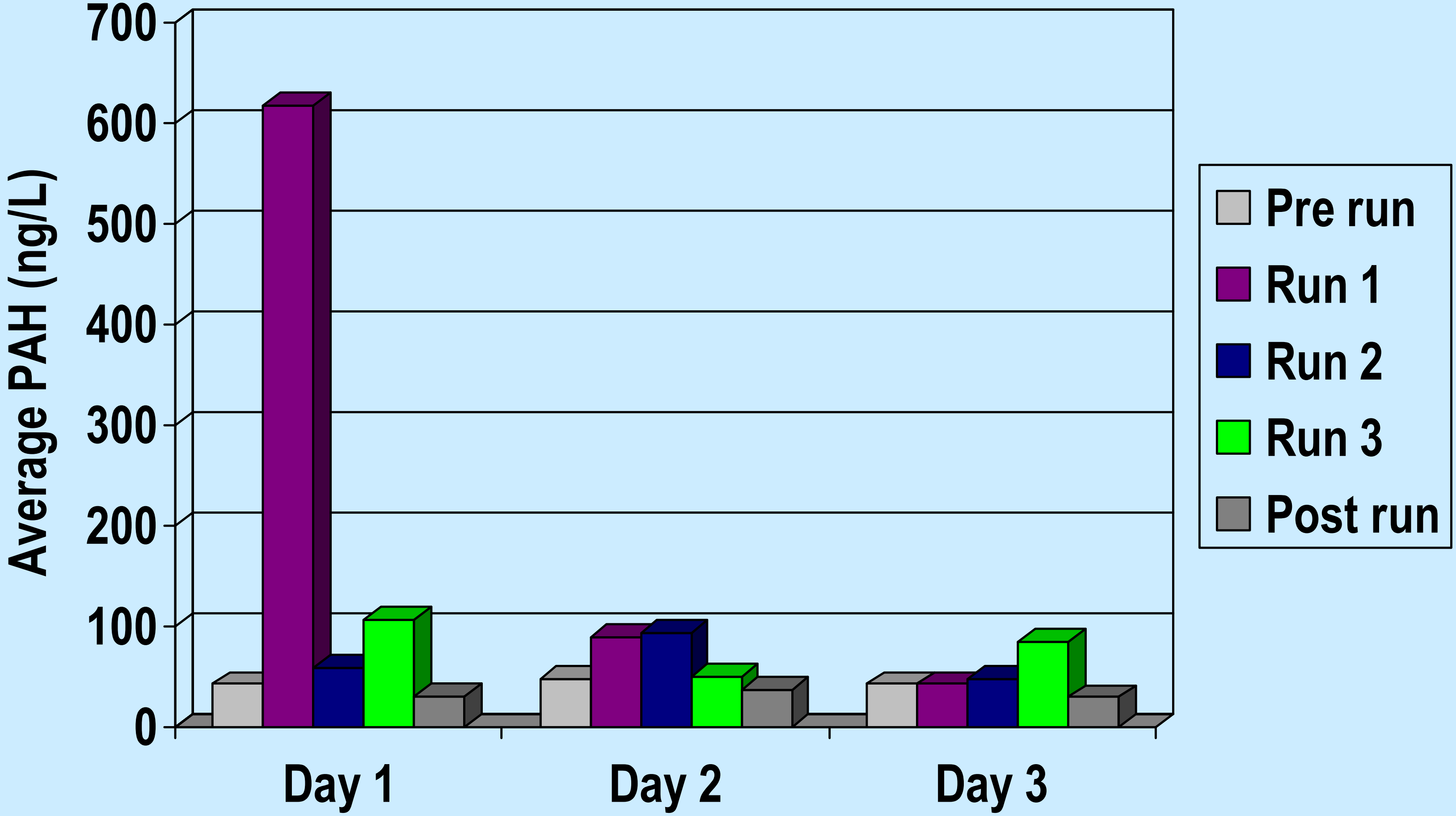
Turbidity and Resuspension

Boston Harbor Case Study



Turbidity and Resuspension

Eagle Harbor Case Study

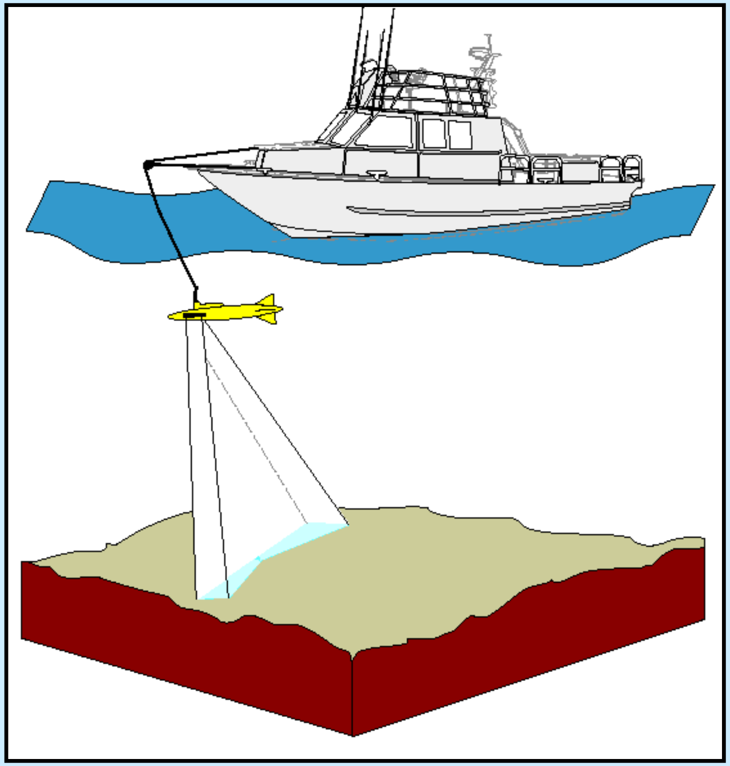


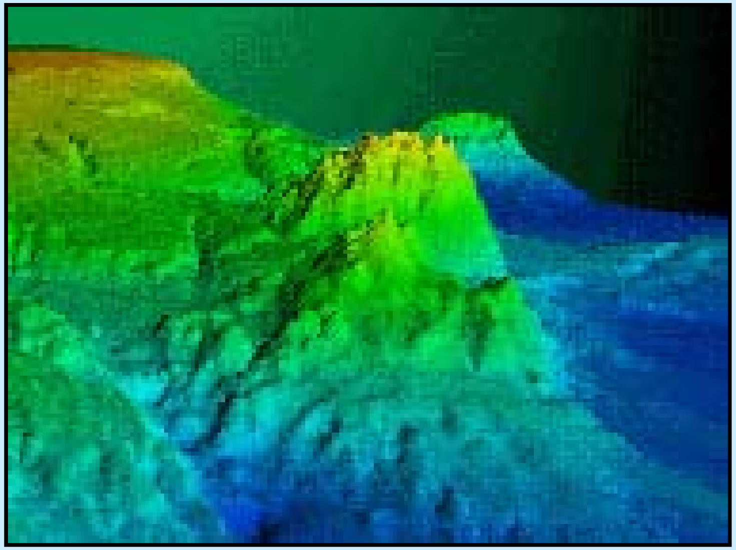
Turbidity and Resuspension Observations

- Contaminant resuspension
  - High turbidity at both sites, mostly due to capping material
  - Relatively minor contaminant suspension measured at both sites
  - Highest contaminant suspension measured during initial capping events
  - Rapid contaminant dissipation after capping
- Neither capping approach led to less contaminated sediment resuspension

Monitoring Tools

- Monitoring objectives
  - Proper cap construction and operation
  - Need for cap repairs
- Cap monitored during and after placement
  - Sediment coring
  - Bathymetric surveys
  - Settling plate
  - Sediment-profiling camera
  - Water profile meters

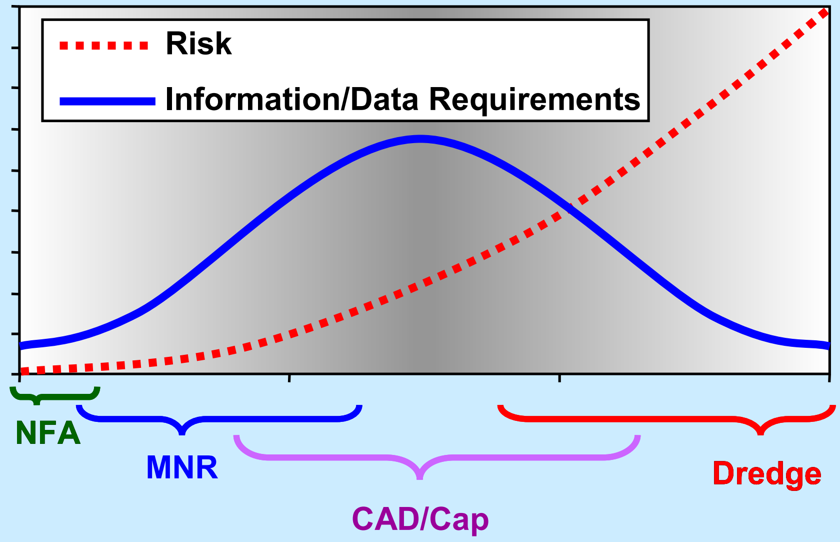




Pictures from Pacific Seafloor Mapping Project
http://walrus.wr.usgs.gov/pacmaps/

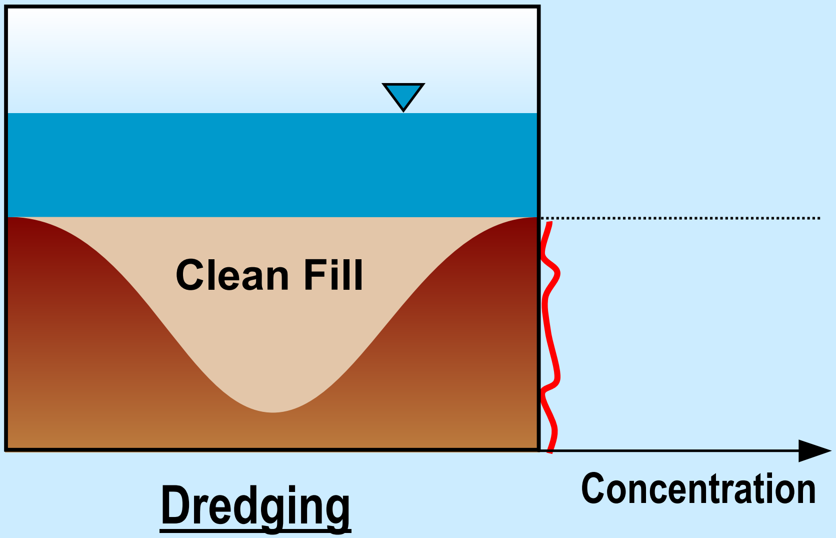
Sediment Cleanup Alternatives
Overview

- Establishing Cleanup Criteria
- Natural Recovery
- In Situ Capping
- Environmental Dredging
  - Principles and Application
  - Advantages/Limitations
  - Effectiveness and Cost
  - Disposal of Dredged Sediments
  - Treatment and Beneficial Use
- In Situ Remediation (innovative treatment alternatives)
- Summary



Dredging Principles and Application

- Definition: The process of transporting sediment from underwater to surface
- Wet excavation
- Dry excavation
  - Marshes or temporarily dry conditions
  - Dewatered sites
- Sediment collection: barges, or piped directly to shore
- Silt curtains
- Environmental windows



Navigational Versus Environmental Dredging

Navigational

- Depth-based removal
- Production driven
- High production rates
- Large volumes
- Low cost
- Disposal options vary

Environmental

- Risk-based removal
- Driven by RAOs
- Lower production rates
- Smaller volumes
- High cost
- More restricted disposal

Information/Data Requirements

- Chemical
  - Contaminant distribution
  - Contaminant characteristics (treatability, stability, etc.)
  - Treatment or disposal requirements
- Geotechnical
  - Particle size characteristics
  - Sediment bearing capacity (for disposal)
  - Water content and dewaterability
- Site Logistics
  - Accessibility
  - Fish windows
  - Navigation
  - Depth to sediment and sediment volume

Implementation Issues

- Site Considerations
  - Mobilization (heavy equipment)
  - Minimize impact on surrounding area
  - Access to contaminated sediments
  - Presence of debris and other potential obstructions
- Technical Considerations
  - Large volumes of material must be handled
  - Dewatering/size separation/treatment requirements
  - Presence of contaminant mixtures
- Site Constraints
  - Environmental dredging requires limiting sediment suspension
  - Minimize removal of uncontaminated sediments
  - Environmental time constraints (e.g., fish windows)

Hydraulic Dredge

- Cutterhead or hopper/draghead
- Pump sediment to the surface
- Sediment is held on vessel or pumped to shore
- Dredges large volumes rapidly
- Sweeps large areas uniformly
- Excellent for navigational dredging
- Disadvantages
  - High water content
  - Requires 2–3 ft standing water
  - Hoppers require deeper water
  - Hampered by rocks and debris

http://www.ihcsystems.com

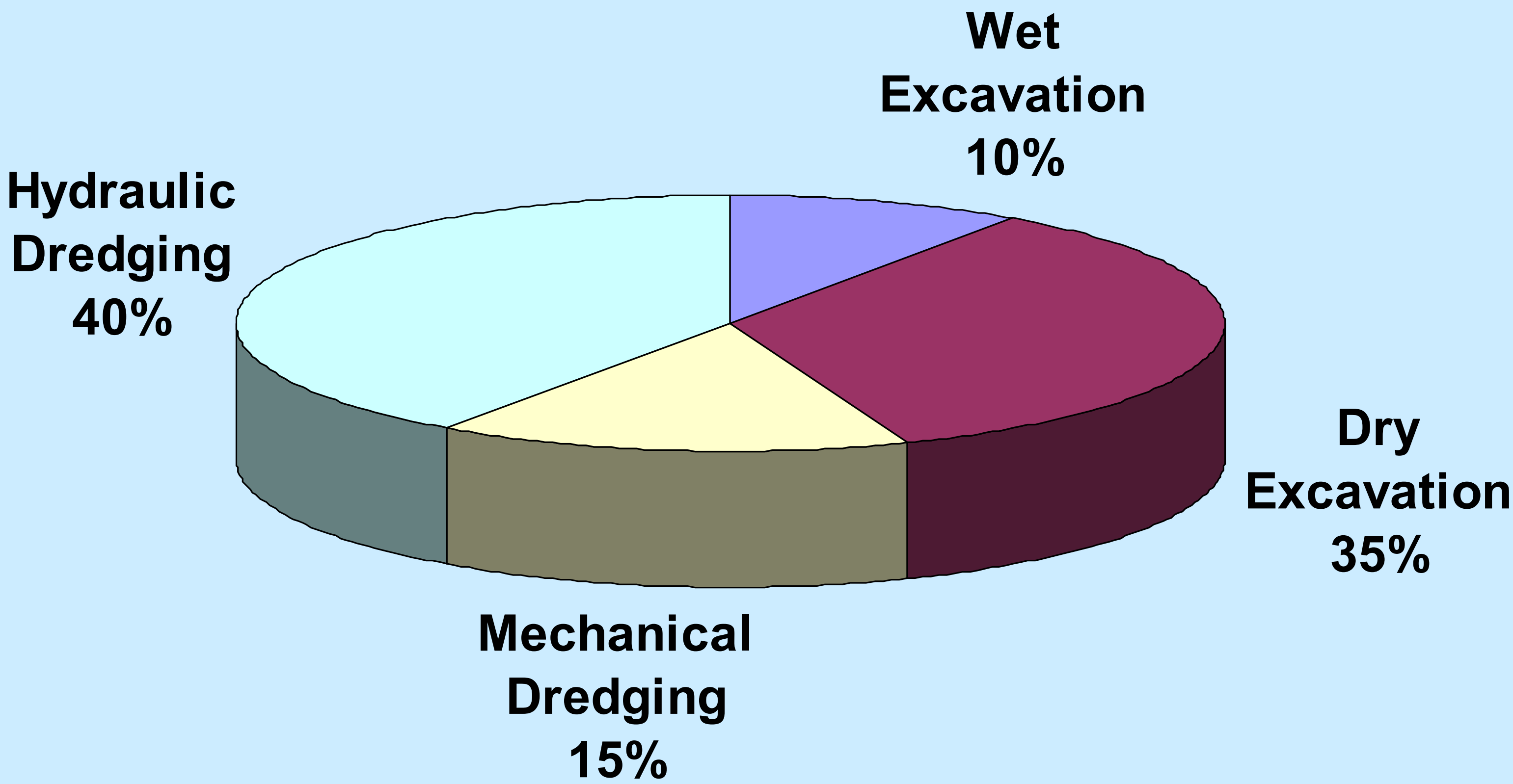
http://www.mobilepulley.com

Mechanical Dredge

- Buckets, clamshells, backhoe
- Lifts sediment to the surface
- Can operate from shore or barge
- Good for hot-spot dredging
- Good for debris removal
- Relatively low water content
- Disadvantages
  - Significant turbidity
  - Limited depth
  - Slower than hydraulic dredging
  - Less uniform than hydraulic dredging

Pictures from http://www.pyr.ec.gc.ca/ep/ocean-disposal/disposal_gallery_e.htm

Types of Dredging



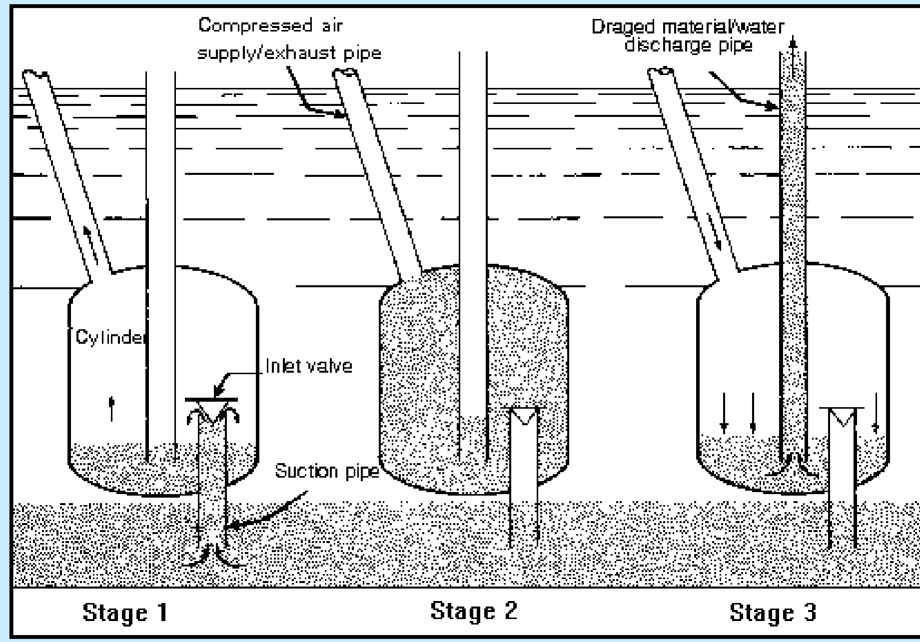
General Electric HudsonVoice Database (www.hudsonvoice.com)

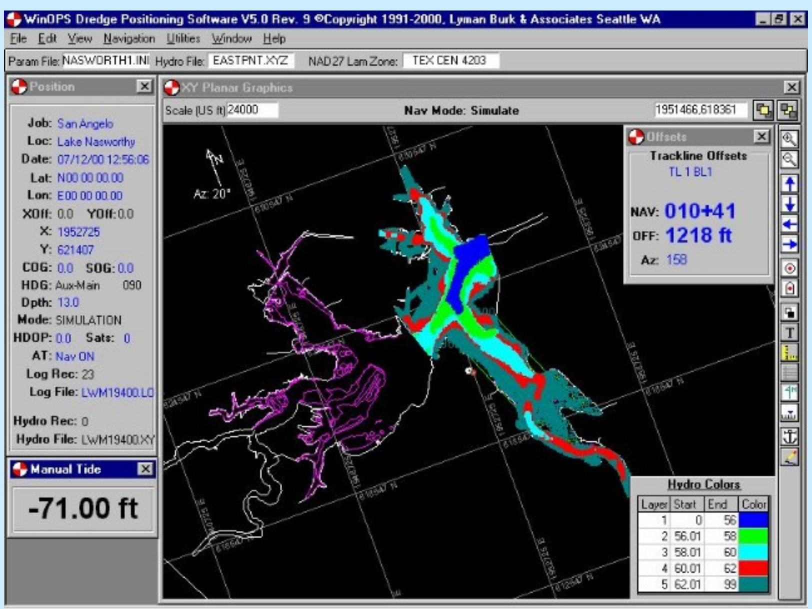
Principles and Application

Innovations

Pneumatic dredging:
high capacity
with reduced suspension

http://www.on.ec.ge.ca





Computer-operated sensory arrays
and controllers

http://www.zerowasteamerica.org/Landfills.htm

Sediment Cleanup Alternatives
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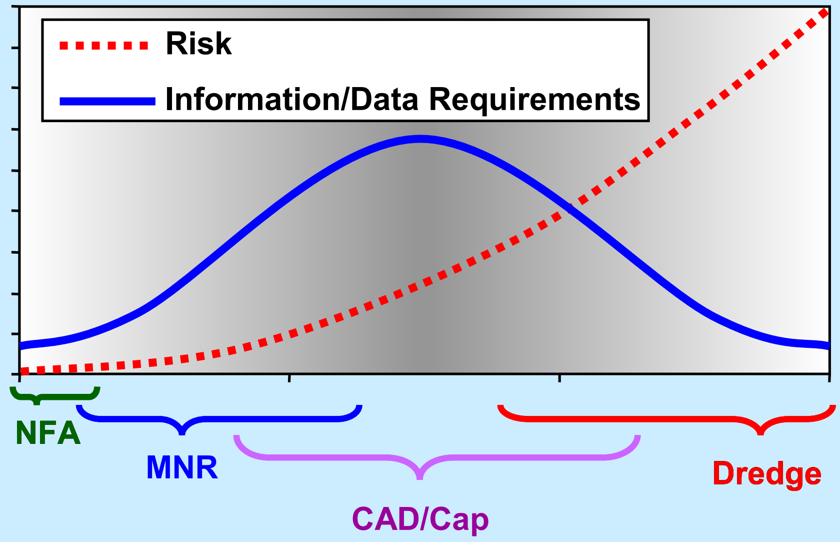

Advantages and Limitations

- **Advantages**
  - Permanent contaminant removal
  - Relatively rapid, once mobilized
  - Well developed technology
  - May be cost competitive (assuming no treatment or transportation)
- **Limitations**
  - **High cost:** dewatering, separation, treatment, disposal
  - Contaminant resuspension
  - Short-term exposure
  - Difficulty achieving low concentration levels
  - Benthic habitat disruption
  - Negative public perception
  - Boulders/debris/complex environments hamper dredging

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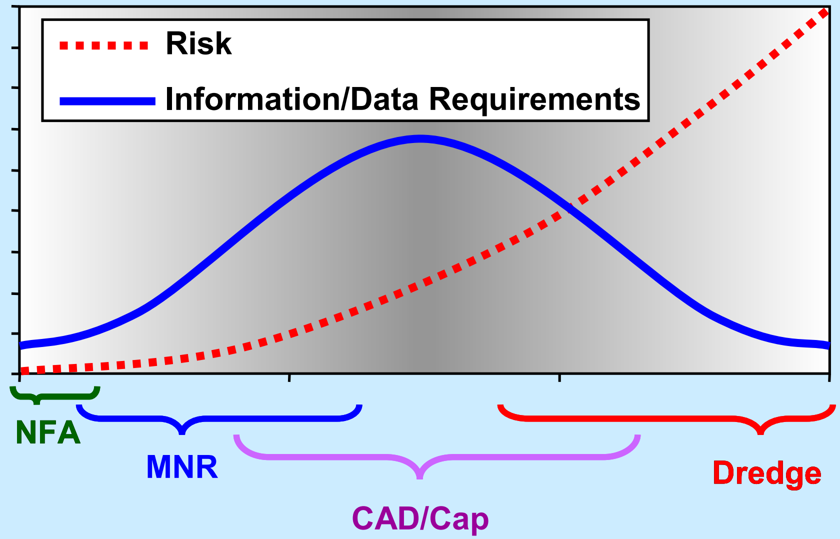
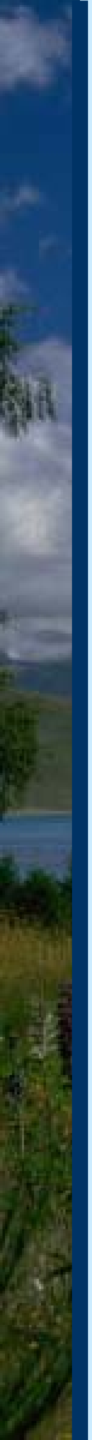


Dredging Effectiveness

- Definition
  - The degree to which contaminated sediment removal via dredging achieves acceptable reduction in risk to human health and the environment
  - Effectiveness $\neq$ quantity, at all sites
  - Net risk reduction, based on RAOs
- Evaluation criteria
  - Volume (sediment and contaminant mass)
  - Achieving predetermined sediment depths
  - Achieving surface sediment concentrations
  - Post-dredging performance criteria (e.g., fish tissue reductions)



Environmental Dredging Remedial Action Objectives

- Reduce human health risk (at 5 sites)
- Reduce contaminant levels in fish (at 1 site)
- Reduce or eliminate ecological impacts (at 4 sites)
- Source control and mass removal (at 20 sites)

General Electric HudsonVoice Database (www.hudsonvoice.com)

Reported Project Difficulties/Challenges

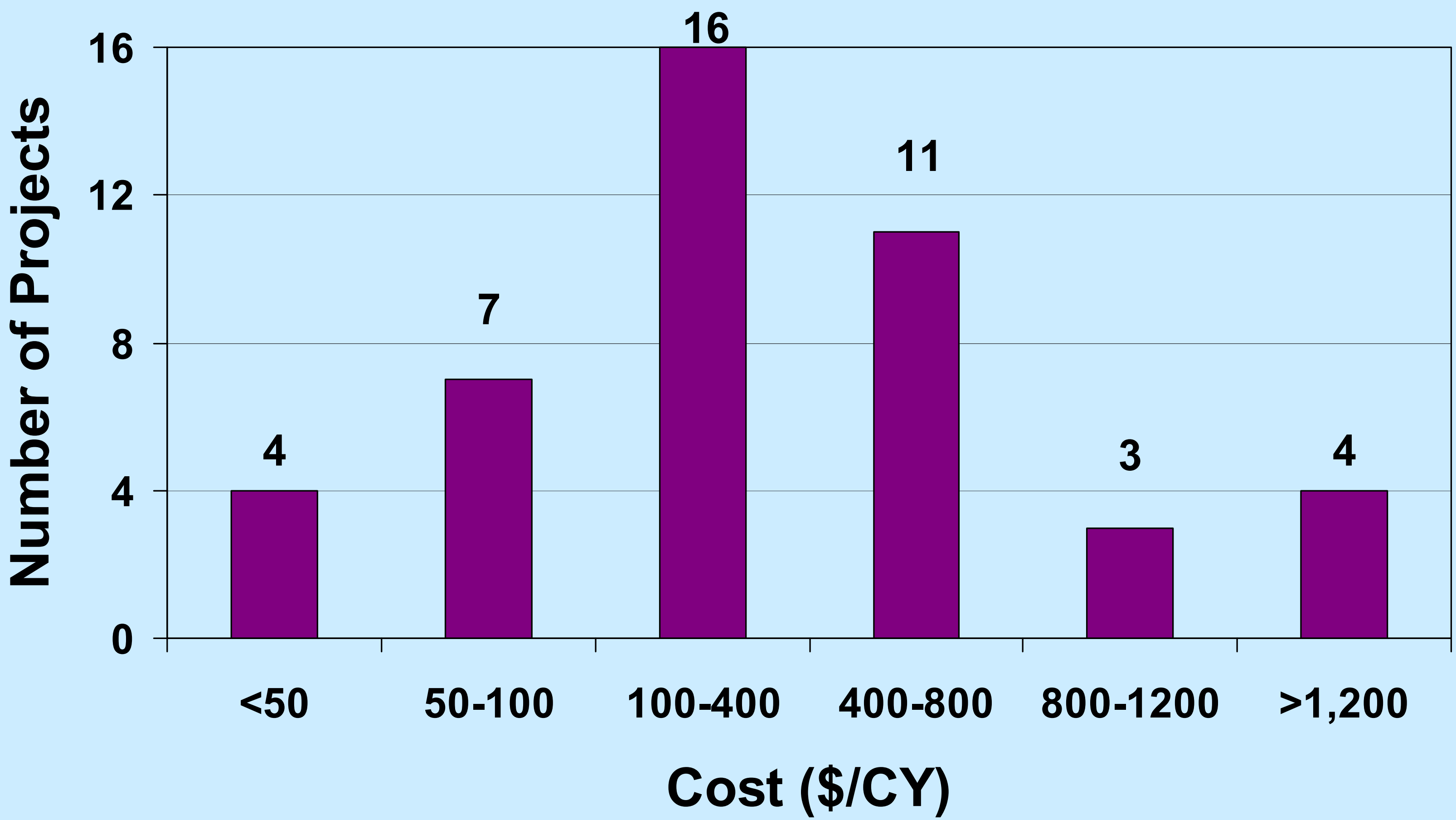
- In general, contaminant mass removal high, but reaching residual cleanup goals is difficult
- Source removal to pre-designated depths is typically successful
- Rocks, boulders, or other debris limited access and effectiveness
- Limited dredging time reduces efficiency
- Contaminant release and sediment resuspension
- Other reported challenges

General Electric HudsonVoice Database (www.hudsonvoice.com)

Environmental Dredging Costs

- Dredging alone (no treatment) < $10/cy
- Environmental dredging costs 300 – 500x navigational dredging
  - Slower pace to ensure contaminant capture
  - Sediment suspension controls (silt curtains, time)
  - Dewatering/size separation/dewatering
  - Transportation
  - Extensive monitoring requirements
- New technologies focus on cost savings
  - Increase dredging efficiency
  - Remove exact amounts of material (minimize dredging clean sediments)
  - Minimize suspension of contaminated sediments

Costs (Including Treatment/Disposal)



General Electric HudsonVoice Database (www.hudsonvoice.com)

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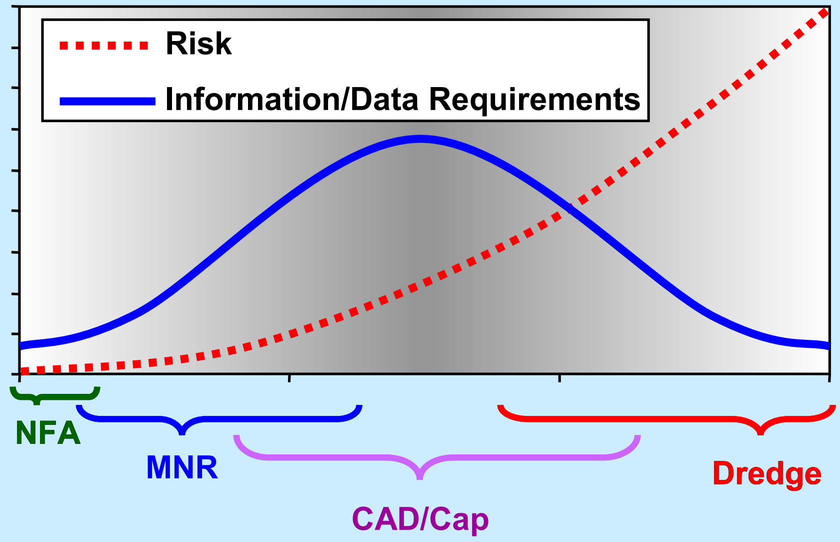
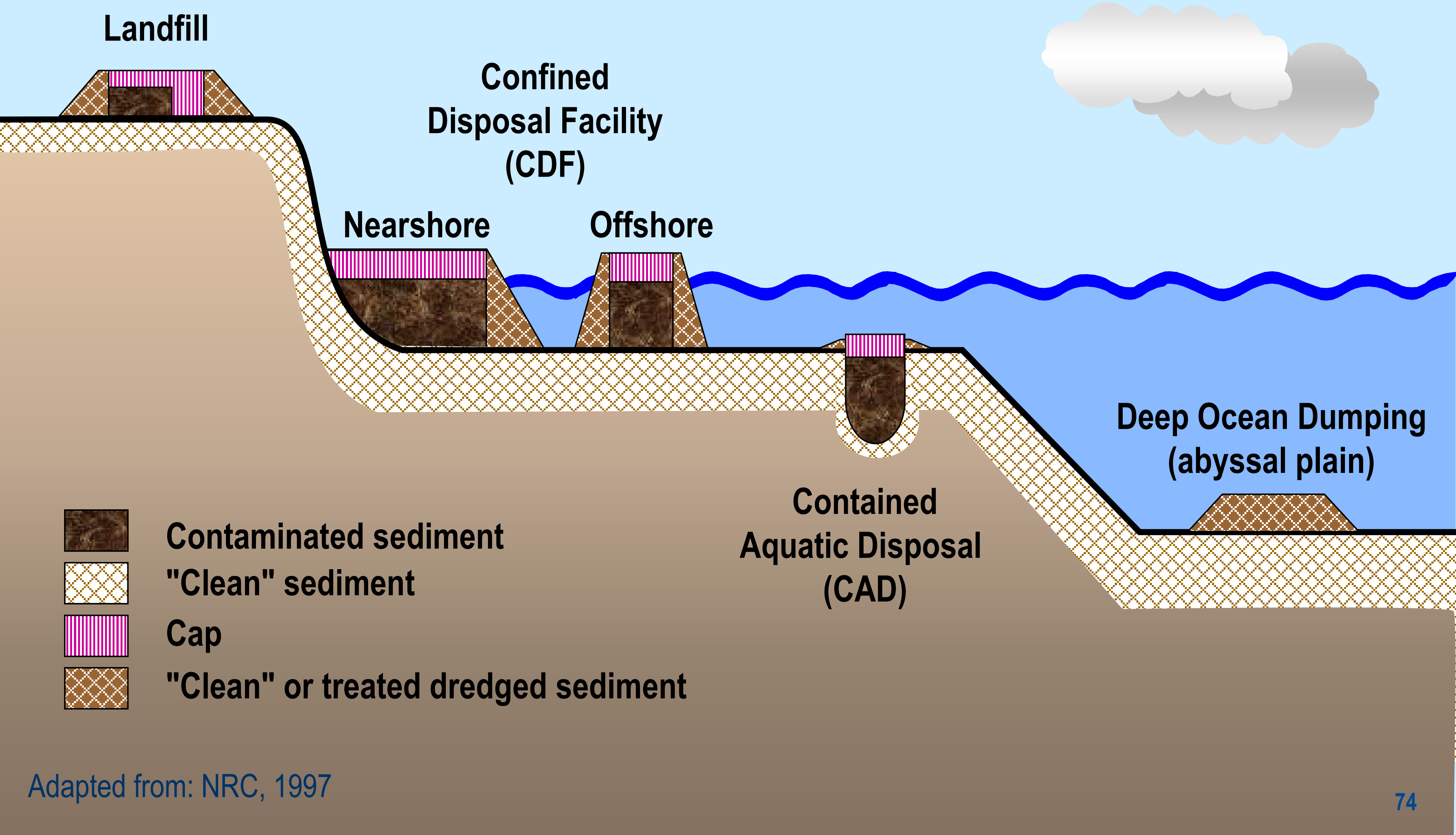


Disposal Options



Adapted from: NRC, 1997

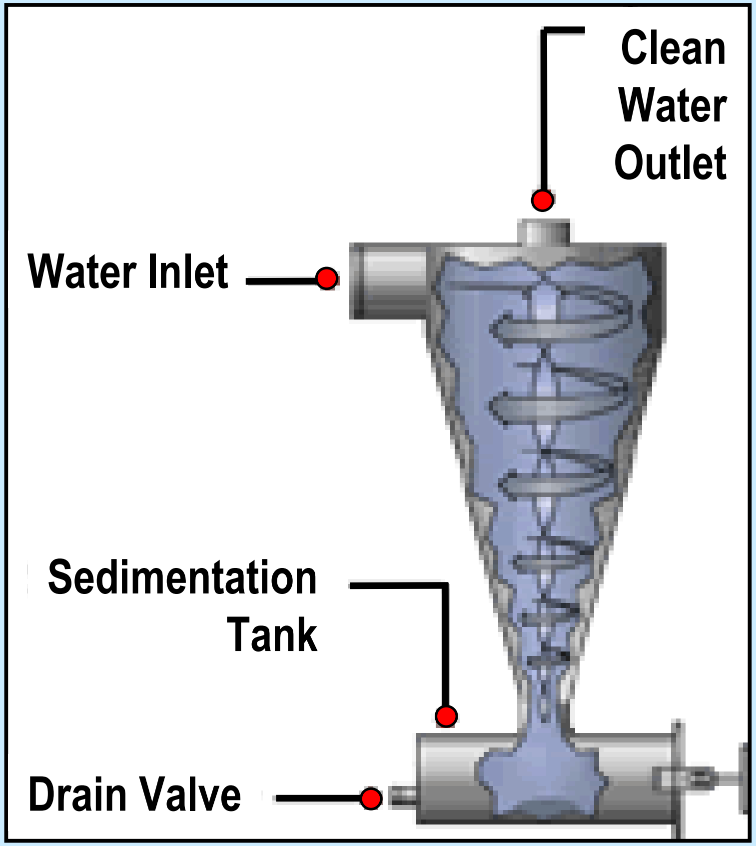
Regulations and ARARs

Sediment Treatment and Disposal Standards

- **Ocean Disposal** – MPRSA Section 102, "Green Book", Evaluation of Dredged Material Proposed for Ocean Disposal - Testing Manual (EPA 503/B-91/001)
- **Beneficial Use** – CWA, WRDA, Evaluating Environmental Effects of Dredged Material Management Alternatives (EPA 842/B-92/008)
- **Land Disposal** – RCRA LDRs, CWA for sites with regulated "return flow" or impact to wetlands
- **Inland Water Disposal** – CWA Section 404, "Gold Book" Quality Criteria for Water (EPA 440/5-86/001), plus updates

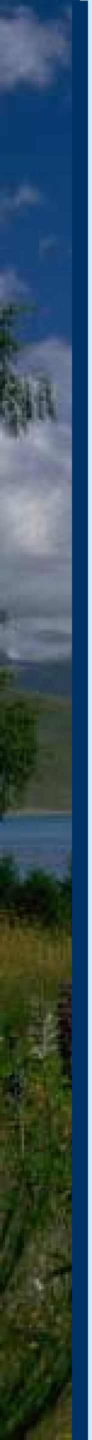
Pre-Treatment

- Screening/Size Separation
  - Large scale debris removal
    - backhoe/clamshell
  - Small scale debris removal
    - vibrating screens, trommels, grizzlies
  - Particle size separation techniques
    - hydrocyclones, screw classifiers, gravity separation
- Dewatering
- Wastewater Treatment



Hydrocyclone Sand Separator

Figure from http://www.netafimusa.com/ag/products/filtration_hydrocyclone.asp

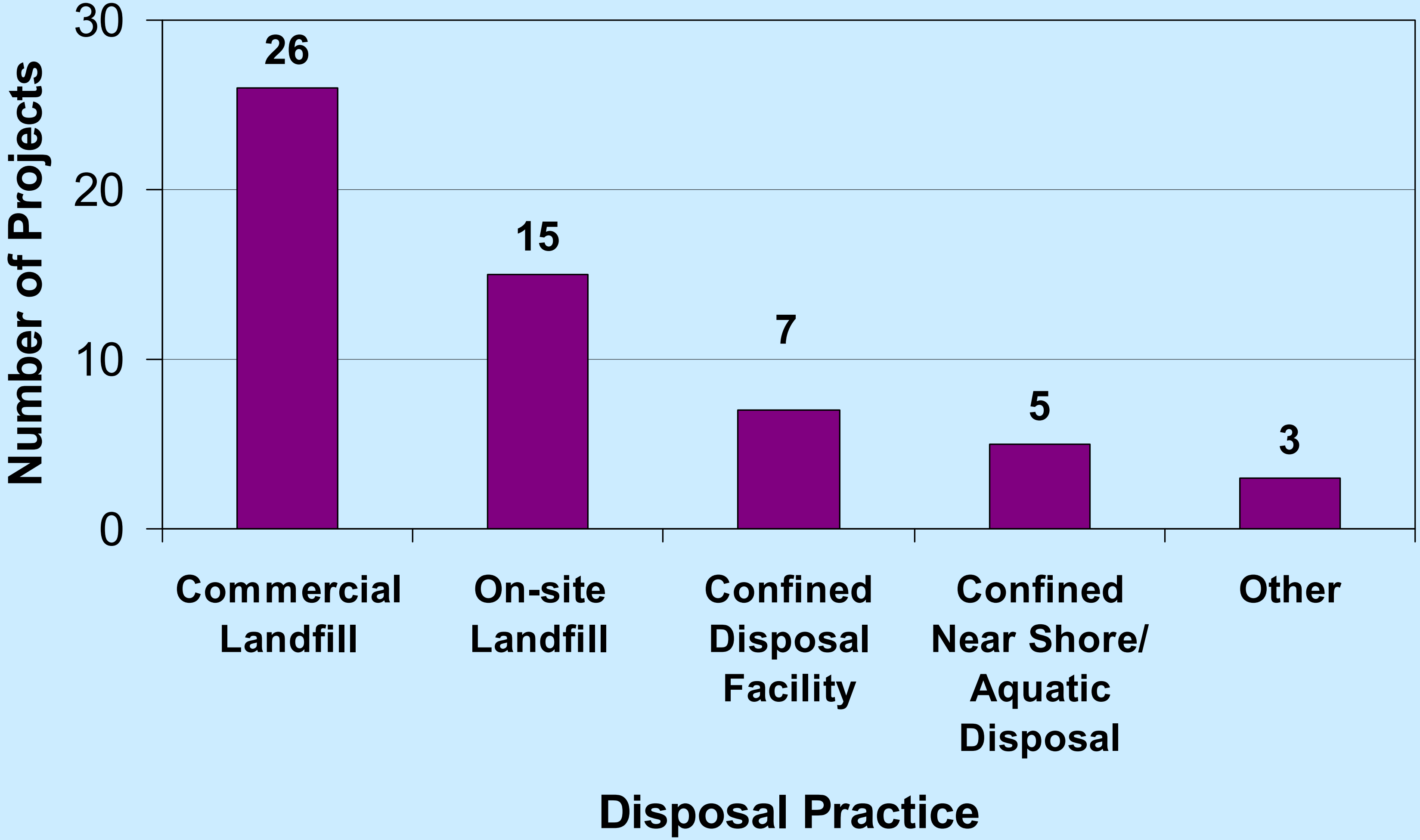


Pre-Treatment Costs

Method	Cost ($/CY)
Air drying (passive)	$4 to $7
Filtration	$8
Centrifuge	< $8
Gravity thickening	< $8
Pretreatment (Size Separation, Dewatering, Wastewater Treatment)	$15 to $75

Based on Table 15 in the California State Water Resources Control Board Guidance On Development of Proposed Regional Toxic Hot Spot Cleanup Plans (1997) and Sierra Club Healthy Harbors (2001).

Disposal Options – Reported Trends



General Electric HudsonVoice Database (www.hudsonvoice.com)

CDFs and CNDFs

Advantages

- Less expensive than landfills
- Proximity to site can reduced handling and transport requirements
- Beneficial use: brownfield development
- Treatment of sediments within CDF/CNDF possible

Limitations

- Contaminants are not destroyed
- Potential for contaminants leaching
- Potential plant or animal exposure to contaminants
- Long-term monitoring
- New CDFs are difficult to site
- Increasingly stringent regulatory controls

Pictures from USACE Confined Disposal Facilities on the Great Lakes (1998).
Available at http://www.lrd.usace.army.mil/gl/caf98.pdf

CADs

Advantages

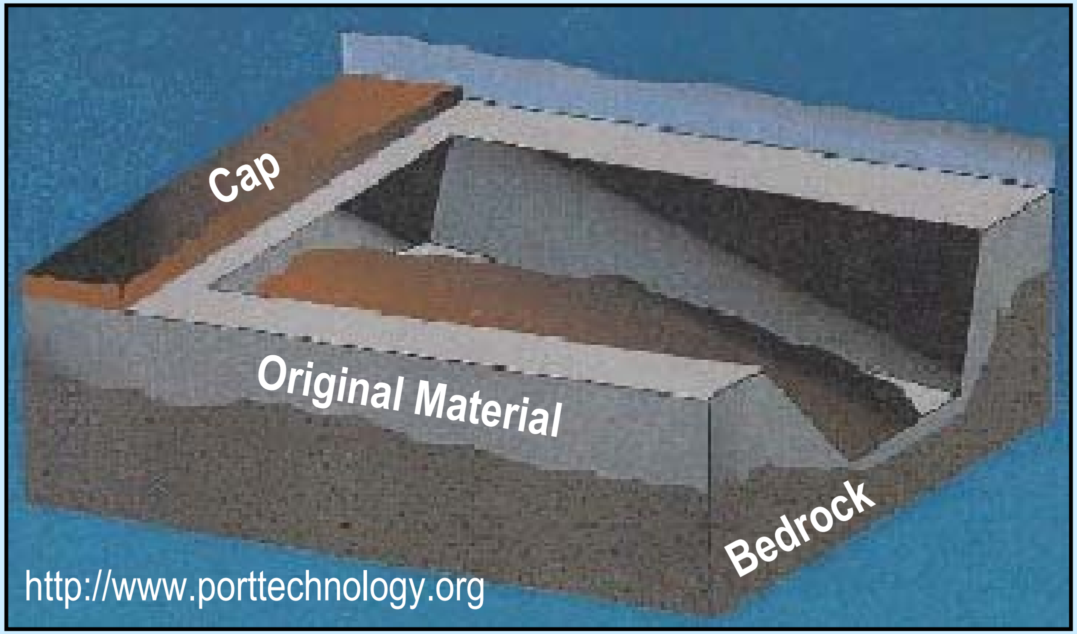
- Strategic placement within natural/excavated depressions
- Minimizes transportation
- Little or no pretreatment
- No dewatering
- Capping minimizes future contaminant release
- Cost-effective

Limitations

- Long-term monitoring
- New CADs are difficult to site
- Contaminant resuspension/release may occur during placement
- Contaminants not removed from the aquatic environment
- Risk of cap breach by storm events or benthic activity
- Increasingly stringent regulatory controls

Confined Aquatic Disposal Cell

Typical Plan and Section



Upland Disposal

Advantages

- Engineered landfills reduce potential contaminant migration
- Removes contaminated sediments from aquatic environment
- Can be cost-effective
- Future beneficial brownfield use

Limitations

- Pre-treatment requirements
- Cost easily escalate: transportation, dewatering, stabilization/solidification
- Limited landfill space
- Long-term monitoring requirements

Pictures from http://www.zerowasteamerica.org/landfills.htm

Disposal Costs
(in addition to dredging costs)

Disposal Option	Cost ($/CY)
Commercial landfill	$30 to $300
On-site landfill	$3 to 20
CDF or CNDF	$15 to $50
CAD	> $50

Based on Table 15 in the California State Water Resources Control Board Guidance On Development of Proposed Regional Toxic Hot Spot Cleanup Plans (1997) and NRC Contaminated Sediments in Ports and Waterways: Cleanup Strategies and Technologies (1997)

CDF Case Study
Eagle Harbor, WA

- Hg-contaminated sediment: underpier = 1,000 CY; open-water = 2,000 CY
- CDF constructed over intertidal sediments, adjacent to ferry terminal; increased upland acreage by 20%
- Cost: $3M to $4M

Shipyard before remediation — Berm under construction — Remedial action complete

HARTCROWSER

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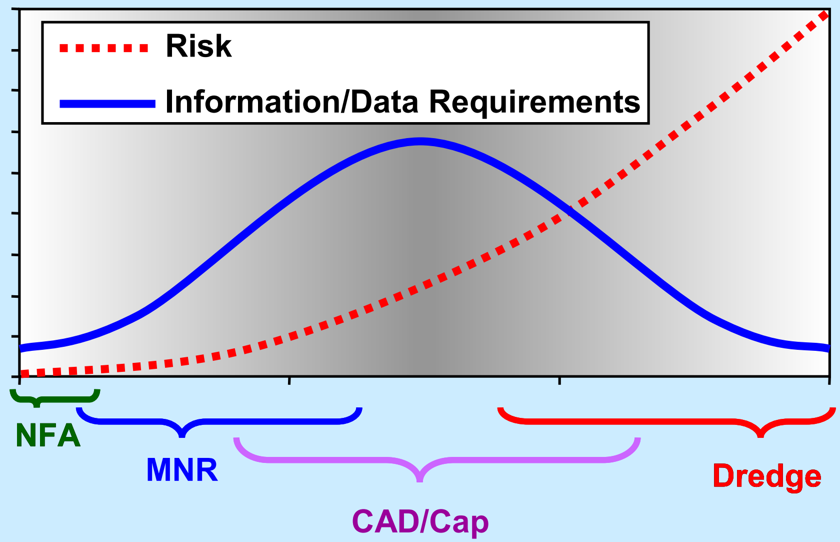
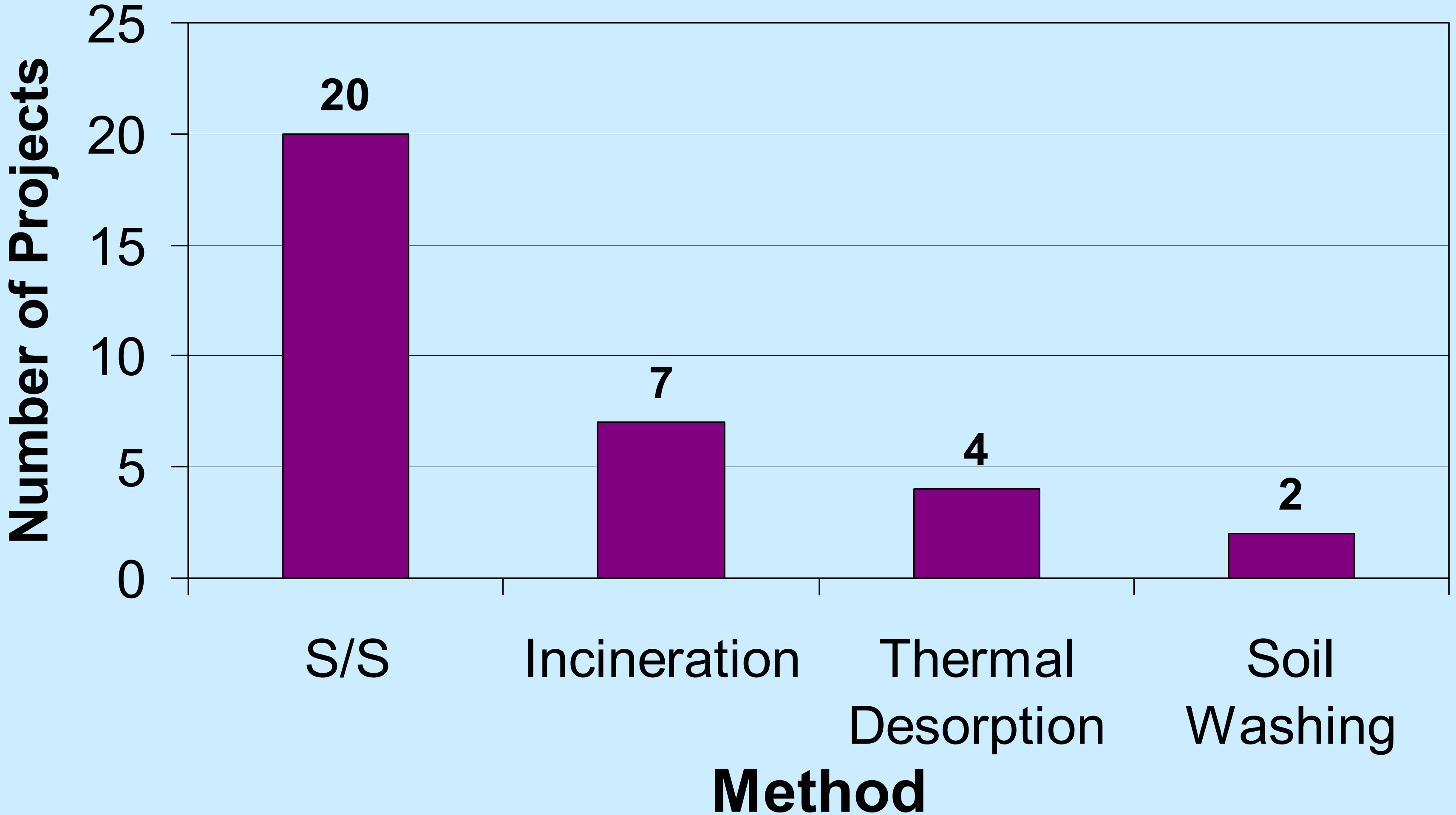


Treatment Methods – Costs

Treatment Process	Treatment Technology	Typical Cost ($/CY)
Thermal	Thermal desorption, incineration, vitrification	$110 to $1,350
Chemical	Sediment washing	$81 to $330
	Solidification/Stabilization	$81 to $392
Biological	Biopile/composting, phytoremediation	$20 to $270

Costs based on Mulligan et al. 2001
Assumes sediment density of 1.35 ton/cy

Reported Trends



General Electric HudsonVoice Database (www.hudsonvoice.com)

Advantages and Limitations

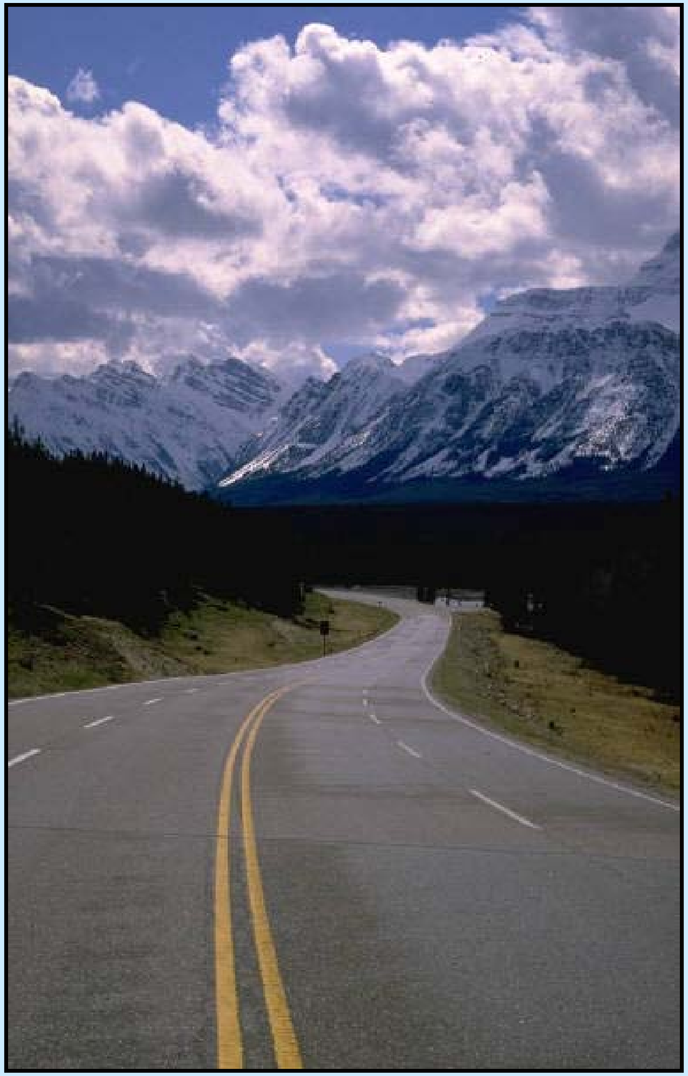
Advantages

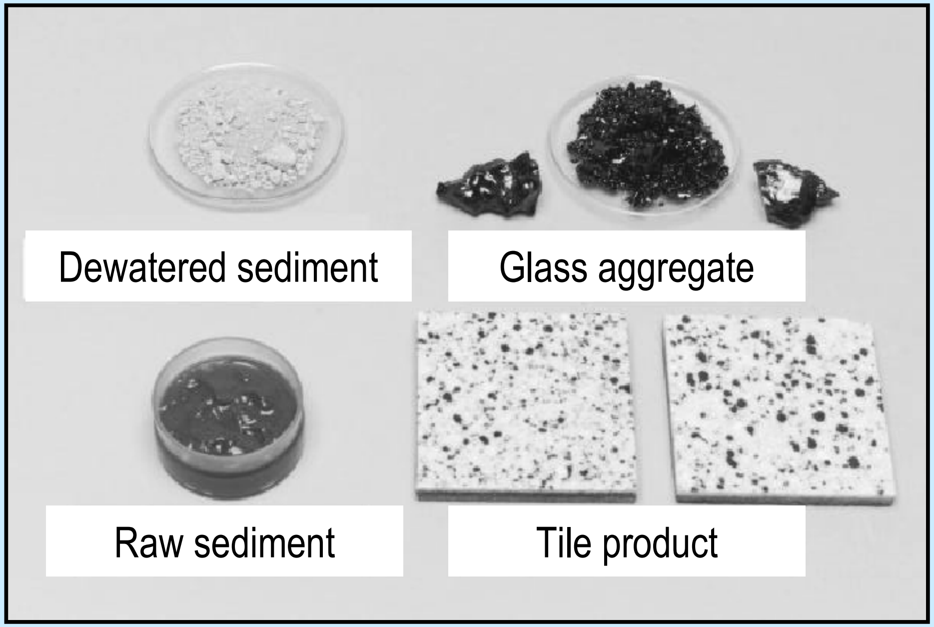
- **Contaminants permanently destroyed or removed from the environment**
- Alternative to direct disposal
- Capacity of existing disposal facilities is increasingly limited
- Potential beneficial use: sale of product can offset treatment costs

Limitations

- **Cost, cost, and cost**
- Treatment may result in release of other harmful chemicals (e.g., thermal release of dioxins)
- Beneficial use
  - Ensure product safety and quality
  - Product marketability
- Negative public perception of some technologies (especially thermal)
- Space requirements for treatment/disposal

Beneficial Use Options





Source: McLaughlin, et. al., Decontamination and Beneficial Reuse of Dredged Estuarine Sediment: The Westinghouse Plasma Vitrification Process. http://www.bnl.gov/wrdadcon/publication/articles/westinghouse-weda.pdf

Beneficial Use Options

Beneficial Use Material	Treatment Temperature/Approach	Contaminant Removal
Manufactured soil and fill (Biogenesis, Inc.)	Low temp; Particle size separation and soil washing	Low to moderate contamination; ~75% removal
Construction-grade cement (Gas Technology, Inc. [GTI])	High temp (1,000ºC); Dewatering and incineration	Highly contaminated sediments; >99.99% removal of organics; binds metals
Lightweight aggregate (Jay Cashman, Inc./ Upcycle Aggregates)	High temp (1,000ºC); Dewatering, pelletise, and incineration; existing rotary kiln	
Architectural glass tile (Global Plasma System Corp.)	High temp (5,000ºC); Dewatering, plasma torch vitrification	

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In Situ Treatment Concepts

- In Situ Bioremediation
  - Limnofix
  - InStreem™
- Phytoremediation with aquatic plants (conceptual only)
- Sediment reactive/binding materials (conceptual only)
  - Coal-derived material binding (Stanford University)
  - Reactive/binding materials (Battelle)

Advantages and Limitations

Advantages

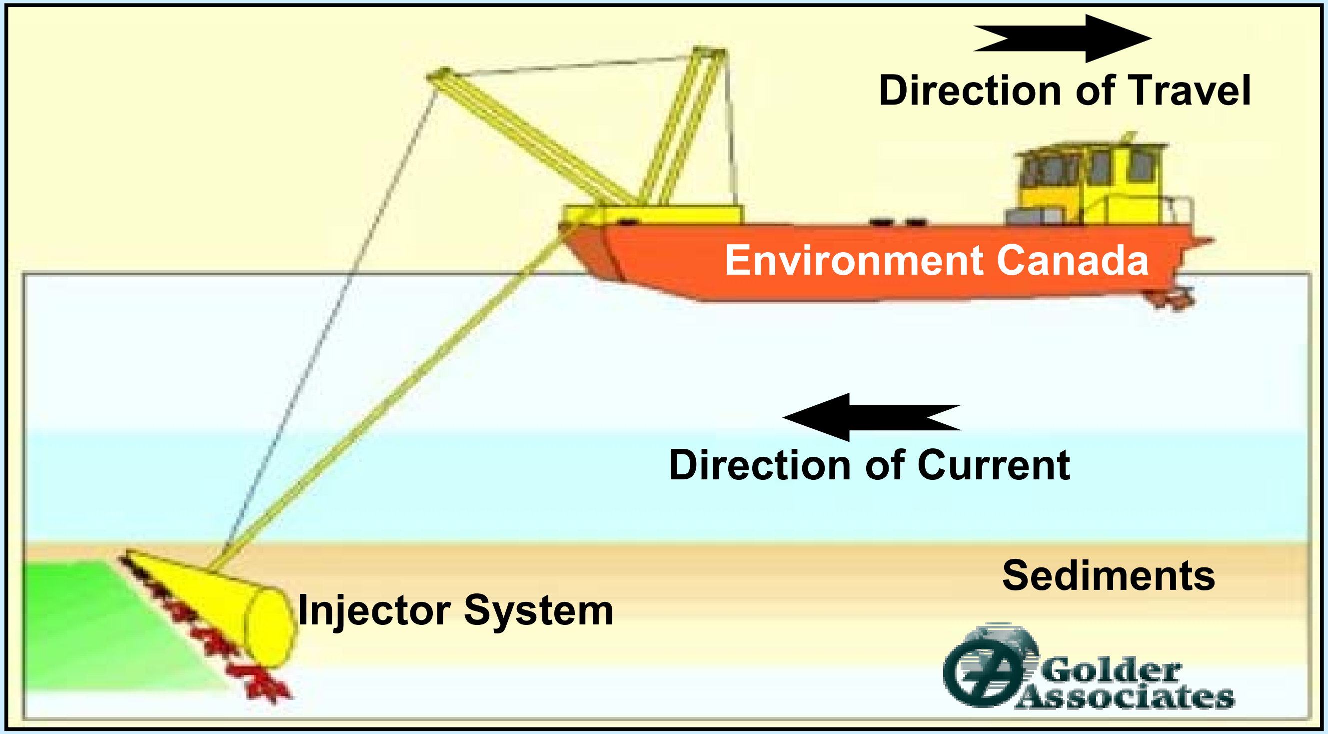
- Limited sediment disturbance
- Ecology remains intact
- Minimize sediment handling
- Reduced toxicity and mobility
- Potentially much lower costs
- Favorable public response and acceptability

Limitations

- Few proven in situ technologies
- May require sediment manipulation and disturbance
- May require long times or repeated treatments
- Complex site conditions and access confound applications
- Complex contaminant mixtures confound treatment alternatives
- Emergent stage of technical development

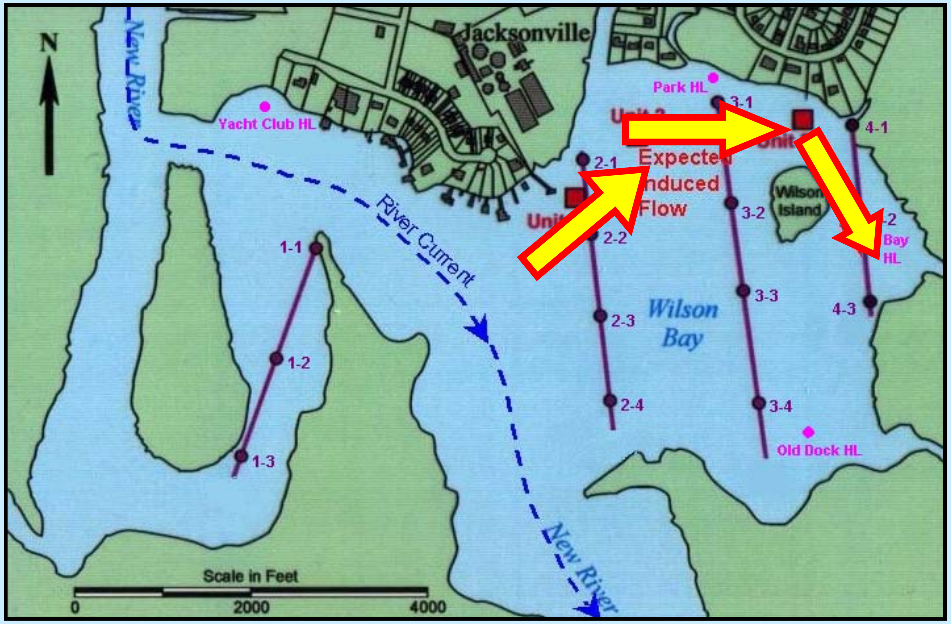
Limnofix In Situ Sediment Treatment
Golder Associates

- Limnofix Hamilton Harbor Results
  - After two years, 64% reduction in PAHs
  - After two years, 57% reduction in TPH



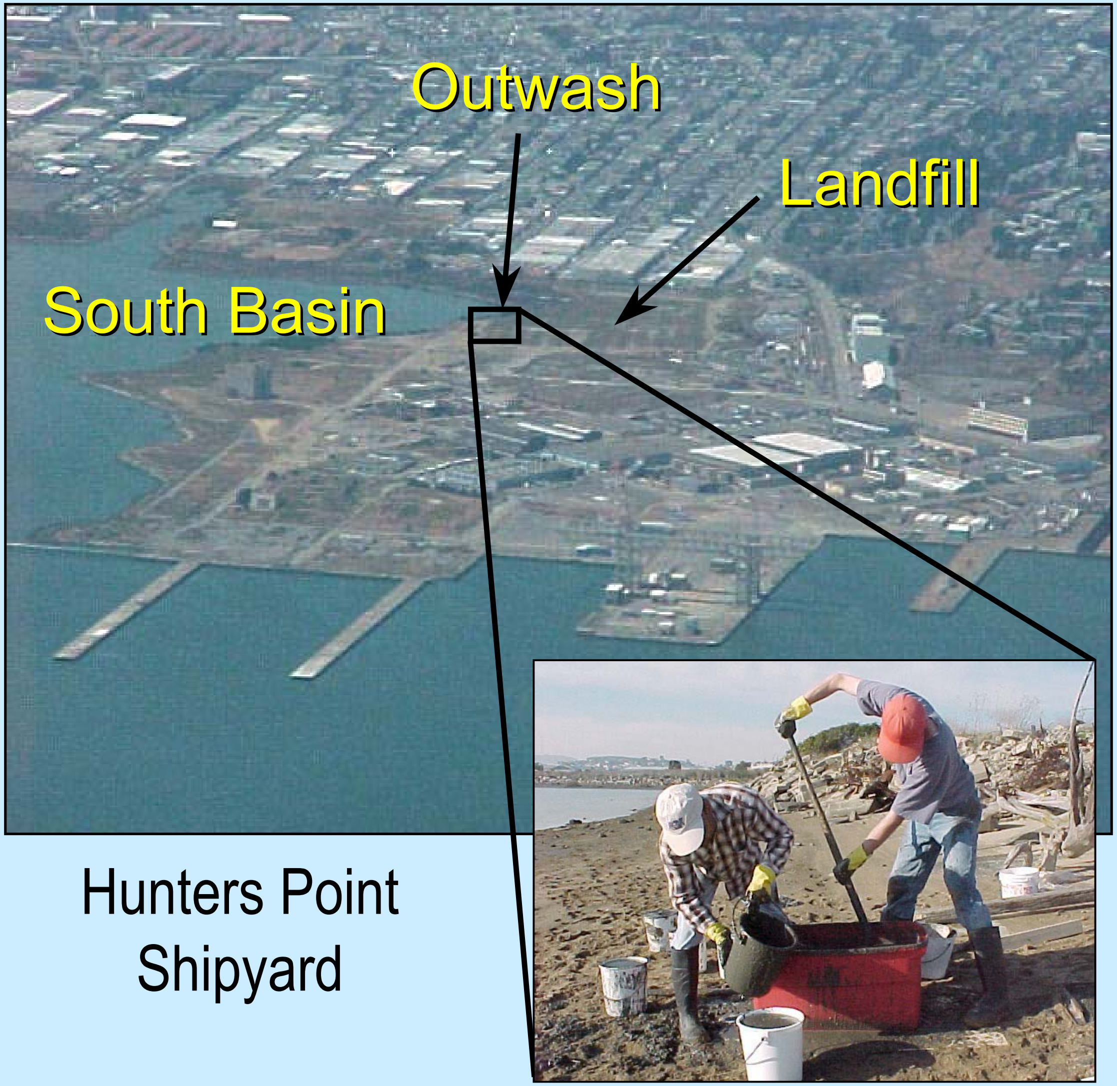
http://www.rtdf.org/public/sediment/minutes/091200/Senefelder/HTML/sld001.htm

InStreem™
Battelle



- Wilson Bay, NC
- 3 units installed
- Low cost: $250K installation + $20K/yr O&M
- Aerated water
- Aerated surface sediments

Coal-Derived Materials
Stanford University

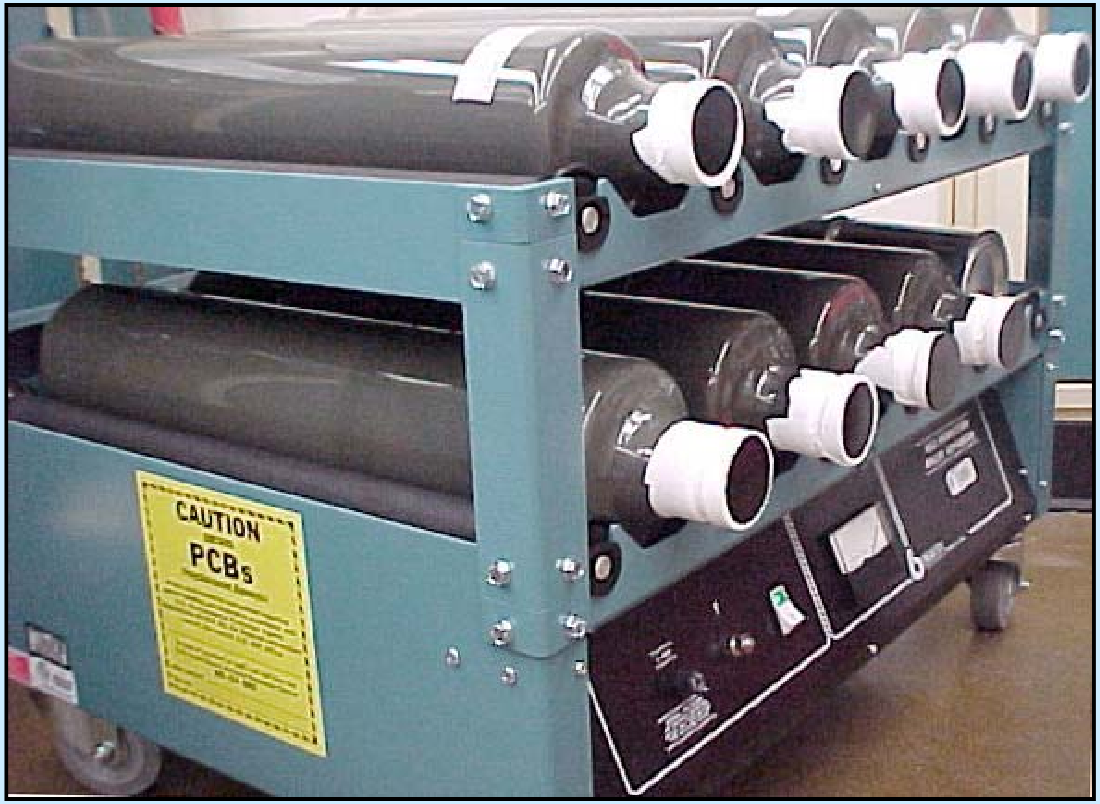


Hunters Point Shipyard

- Effects on availability and binding of PAHs and PCBs in sediment
- Benefit to the survival, growth, and reproduction of marine organisms
- Practicability and regulatory feasibility

Coal-Derived Materials
Physiochemical Assessments

- PCB flux into water
- PCB accumulation in SPMD
- PCB aqueous equilibrium concentration
- PCB desorption
- Particle-scale PCB analysis



Coal-Derived Materials
Biological Assessments

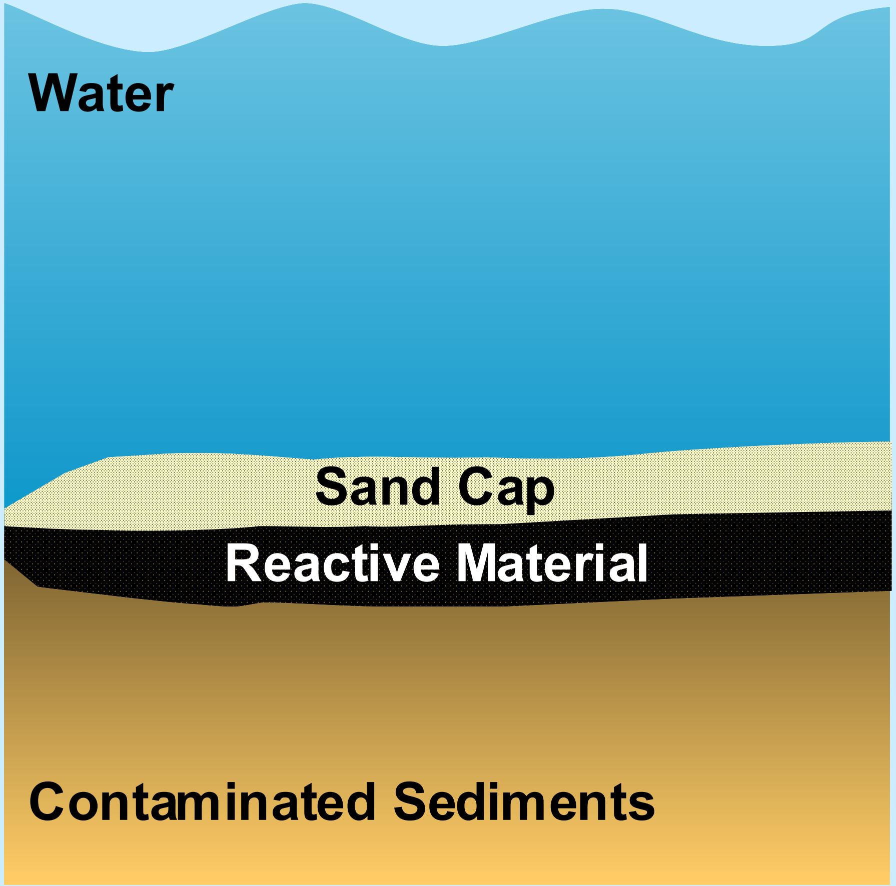
- Sediment toxicity to *Neanthes* and *Leptocheirus*
- PCB bioaccumulation in *Neanthes* and *Leptocheirus*
- PCB bioaccumulation in *Macoma balthica*

Neanthes arenaceodentata

Leptocheirus plumulosus

In Situ Reactive/Binding Materials

- Carbon/Coke/Coal
  - Bind organic contaminants
- Iron (Fe^0)
  - Dechlorination
  - Precipitation
- Activated Aluminum
  - Reactive processes and surface binding



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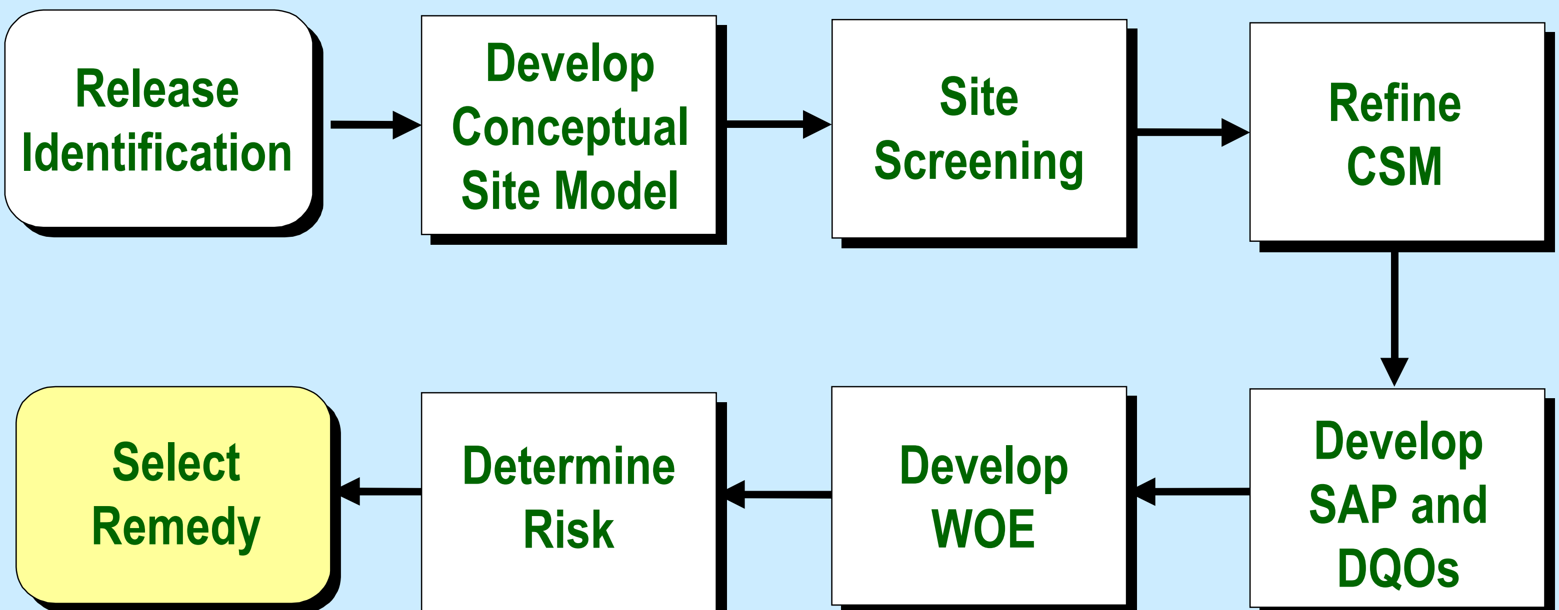
  - Sediments 1
  - Sediments 2

Sediment 1 Summary

Policy, Guidance, and Characterization

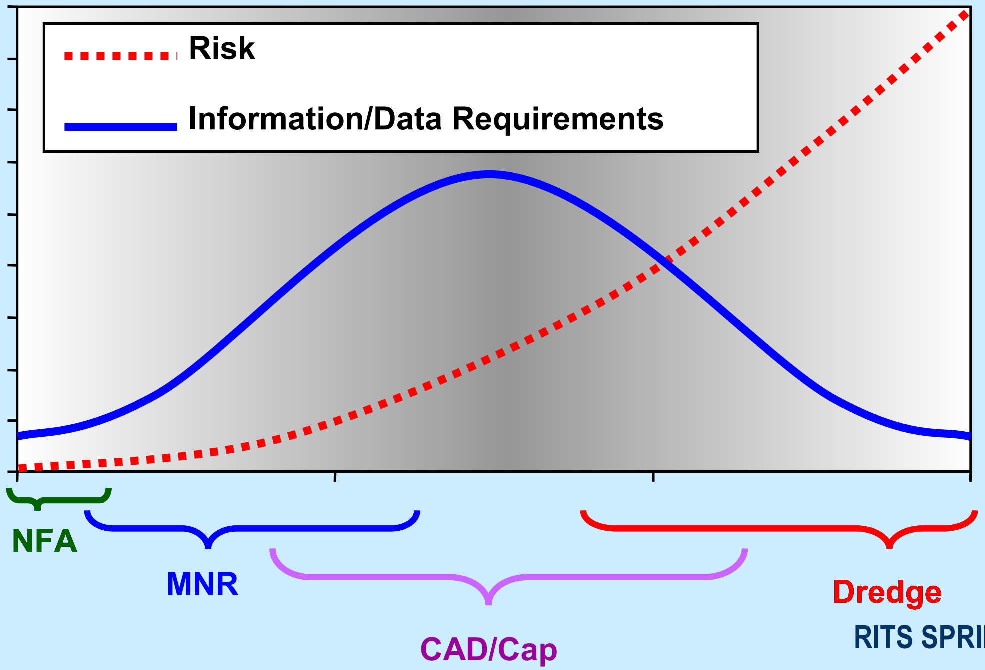
- Sediment Issues
- Chief of Naval Operations (CNO) Policy
- NAVFAC Sediment Implementation Guide
- Site Background and Characterization
- Risk Assessment and Remedial Alternatives



Sediment 2 Summary

Sediment Cleanup Alternatives

- Establishing Sediment Cleanup Criteria
- Natural Recovery
- In Situ Capping
- Environmental Dredging
- In Situ Remediation (innovative treatments)



Sediment 2 – Cleanup Alternatives

References

- NFESC
  - Example Approach for the Development of Site-Specific Preliminary Remediation Goals for the Protection of Ecological and Human Health at Navy Aquatic Sites (SP-2102-ENV).
  - Implementation Guide for Assessing and Managing Contaminated Sediment at Navy Facilities (Draft issued October 2001).
  - Navy Policy for Conducting Ecological Assessments (April 1999).
- U.S. EPA
  - U.S. EPA Contaminated Sediment Management Strategy (1998).
  - The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, Vol. 1: National Sediment Quality Survey (1997).
- NRC
  - Contaminated Sediments in Ports and Waterways (1997).
  - A Risk-Management Strategy for PCB-Contaminated Sediments (2001).
- Other
  - Chadwick, D.B., and S.E. Apitz. 2001. Pathway Ranking for In-Place Sediment Management (PRISM), Strategic Environmental Research and Development Program (SERDP), Project no. CU1209.
  - Palermo, M.R. 1991. *Design Requirements for Capping*. USACE Tech. Note DRP-5-03.
  - Luthy, R., “In Situ Stabilization of Persistent Organic Contaminants in Marine Sediments.” SERDP funded project, Project no. CU1207.

Sedment 2 – Cleanup Alternatives
Key Web Links

- Beneficial Uses
  - http://www.wes.army.mil/el/dots/budm/budm.html
- USACE Dredging
  - http://www.wes.army.mil/el/dots/doer/
  - http://www.wes.army.mil/el/dots/
- Great Lakes Contaminated Sediments Program
  - http://www.epa.gov/glnpo/sediments.html
- NOAA Screening Quick Reference Tables (SquiRTs)
  - http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html